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Beach and Offshore Changes at Point Pelee National Park, Lake Erie 1974 - 1981

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BEACH AND OFFSHORE CHANGES AT POINT PELEE NATIONAL PARK

LAKE ERIE 1974 - 1981

by

John R. Shaw

Bayfield Laboratory for Marine Science and Surveys
Department of Fisheries and Oceans
Burlington, Ontario

October, 1986

SOMMAIRE

Les problèmes d'érosion du littoral du Parc national de la pointe Pelée, sur le lac Érié, remontent loin dans le passé. Toutefois, les niveaux d'eau élevés, enregistrés au début des années 1970, les ont considérablement exacerbés. On a cru en outre que les ouvrages de protection des rivages ainsi que les opérations de dragage aggravaient le problème. Cependant, on ne dispose pas de données suffisantes pour appuyer ces hypothèses.

Cette étude a pour objet d'approfondir nos connaissances sur les phénomènes littoraux en oeuvre à la pointe Pelée, c'est-à-dire quantifier les bilans sédimentaires des zones littorales et décrire les mécanismes de transfert des sédiments. Elle se distingue des autres études par le fait qu'elle se fonde sur le relevé des changements géomorphologiques en cours plutôt que sur le profil paléogéologique ou les techniques de modélisation. Qui plus est, l'étude des phénomènes littoraux du côté canadien des Grands Lacs s'est échelonnée sur 7 ans, une période exceptionnellement longue pour ce genre d'observations. L'étude, parrainée par le gouvernement fédéral, a consisté à mesurer les profils littoraux du périmètre de la pointe Pelée de 1974 à 1981.

Les résultats ont révélé que la pointe Pelée se déplace vers l'ouest et, qu'au cours de la période d'étude, sa superficie a régressé à un taux net de 3 m/année. Signalons toutefois que les pertes plus volumineuses de sédiments littoraux sur la rive est ont coïncidé avec la période de 2 ans qui a suivi les niveaux d'eau exceptionnels de 1973. Depuis,le taux annuel d'érosion de la plage est a chuté d'environ 90 p. 100.

La zone active de sédiments au large s'étend bien au-delà de la zone littorale (laquelle se situe à une profondeur de 1 à 3 mètres) des deux côtés de la pointe. Du côté ouest, lequel gagne sur l'eau, les sédiments s'accumulent de haut en bas du seuil qui forme les assises de la pointe, c'est-à-dire à une profondeur allant de 8 à 9 mètres. Les sédiments au large qui se déposent le long du côté est jusqu'à une profondeur de 6 mètres font partie d'un système de barre extrêmement dynamique. L'accumulation de sédiments au large semble également liée aux fluctuations du niveau d'eau.

Les accumulations les plus importantes de sédiments à l'extrémité de la pointe coïncident avec les périodes d'érosion maximales, en particulier du côté de la rive est. Les sédiments se sont étalés sur une distance de 1,8 kilomètre sur la partie submergée de la flèche. Compte tenu des volumes de matériaux qui ont été déposés à l'extrémité de la flèche, on devrait interdire le dragage dans la zone adjacente jusqu'à un rayon de 3 kilomètres.

ABSTRACT

The problem of shore erosion at Point Pelee National Park on Lake Erie has had a long history, but it became especially critical during the high lake levels of the early 1970's. In addition to record water levels, shore protective structures and dredging activities were also thought to have contributed to the erosion problem, yet this has not been supported by sufficient data.

The objective of this report was to provide a further understanding of shore processses at Point Pelee, with particular reference to quantifying sediment budgets of the shore zones and describing processes of sediment transfer. It differed from previous research in that it was based on ongoing geomorphological changes rather than on a paleogeological approach or modelling techniques. The survey period was also somewhat unique in the study of shore processes on the Canadian side of the Great Lakes, in that it covered a span of 7 years. The project was sponsored by the federal government and consisted primarily of measuring shore profiles arcund the perimeter of Point Pelee from 1974-1981.

Results indicate that Point Pelee migrated west and was losing area at a net rate of 3 m/yr during the survey interval. It should be noted, however, that much of the loss in beach sediments on the east shore occurred during the 2 year period following the record lake levels of 1973. Annual rates of erosion of the east beach have since decreased by about 90%.

The active zone of the offshore sediments extended well below the nearshore zone (1-3 m depth) on both sides of the Point. On the west

side, which is prograding, sediments accumulated along the slope to the base of the Pelee rise, or to depths of 8-9 m. Offshore sediments along the east side that extend to the 6 m depth are part of a highly dynamic submarine bar system. Accumulations of offshore sediments also appeared to be related to water levels.

Accumulations at the tip of the Point were greatest when the shores of Point Pelee were eroding, particularly the east shore. These sediments accumulated on the submerged tip of the spit to a distance 1.8 km. In view of the volumes of material that are deposited on the submerged tip, dredging should not be permitted within a 3 km radius.

ACKNOWLEDGMENTS

I owe the completion of this report to a number of people.

It would not have been possible without the support of Mr. Ross Douglas, A/Director General, and Dr. Allen Walton, Director General, Bayfield Laboratory for Marine Science and Surveys, in approving my educational leave. I am also thankful to my thesis advisor, Dr. Jim Gardner, and Dr. Ron Bulloch, Graduate Officer, University of Waterloo, for their cooperation, patience and occassional kicks in the back side.

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The origin of the monitoring program was the responsibility of Mr. W.S. Haras. For his guidance, wisdom and friendship, I am ever grateful.

The project was sponsored by the Departments of Fisheries and Environment and Parks Canada, and I would especially like to thank the staff of the Point Pelee National Park who were most cooperative and helpful during all phases of the survey.

Many students from the University of Waterloo participated in the Point Pelee surveys over the seven year period. Unfortunately, there are

too many to list, and with the years that have past I would not want to risk accidently omitting any one of them. As a group then, I thank them for their cooperation, hard work, long hours, humour, questions, and many fond memories.

Three others deserve special mention. I will forever be indebted to my family, Heather, Stephen and Juliane, for their understanding, patience and never ending support, especially when I have had to put them on "hold" for the past five months.

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1. INTRODUCTION AND STUDY OBJECTIVES

1.1 Introduction

Point Pelee is well-known to many Canadians. It is a V-shaped peninsula that extends about 12 km into the waters of Lake Erie in Essex County. It is well-known as a National Park; a major staging and nesting area at the confluence of North America's Mississippi and Atlantic Flyways; a unique habitat that supports a vast number of floral and faunal communities not found elsewhere in Canada; and is one of the few remaining significant wetlands in the Great Lakes that has not been sacrificed for development. In fact, Point Pelee has been called the "jewel in the crown of National Parks" (Bayly, 1977), and is enjoyed by 450,000 visitors annually (Parks Canada, 1982).

The southernmost part of Point Pelee was incorporated as a National Park in 1918. For the most part, it comprises a large wetland habitat that is bordered by two converging ridges of sand which serve as natural buffers against the onslaught of Lake Erie storms. To the north of the Park, former lowlands and marshes have been artificially drained for agricultural use, and beach ridges have attracted dense cottage development.

The integrity of the marsh system within the Park depends considerably upon the protective beach ridges. The question of their stability has been a concern since the early 1900's, particularly with the east ridge which is narrow and of low relief, and exposed to a fetch of 200 km. During the record high lake levels of 1972/1973, excessive erosion rates were encountered on the east beach that resulted in the destruction of many cottages in the area and severe recession to the shoreline. For example, as the result of a single storm alone, damage to cottage development in the area was estimated to exceed $250,000, with an average recession of the east beach of 11 m (Coakley et al, 1973).

A number of causes for the sediment-starved condition of the east beach have been proposed. These include natural factors such as high lake levels and currents, and man-made causes such as shore structures and offshore dredging. In spite of numerous actions taken to protect and restore the east beach, beach recovery has not been appreciable.

1.2 Study Objectives

In response to the record damages incurred to shore property during the early 1970's, the governments of Ontario and Canada initiated a long-term erosion monitoring program throughout the lower Great Lakes beginning in 1974. Because of the interest of Parks Canada in supporting the measurements taken at Point Pelee National Park, the monitoring Program was expanded to increase the coverage and frequency of observations to include representative profiles of the entire Park shoreline.

The author presented preliminary results of the first year's data in an unpublished manuscript (Shaw, 1978). The report provided an account of the processes affecting beach changes at Point Pelee such as the wave climate, longshore and bottom currents, ice, and lake levels. In addition, an assessment of the potential effects that offshore dredging operations have on beach dynamics was given.

This report uses the remaining data set, in conjunction with the findings of the preliminary report, to further the understanding of the shore processes operating at Point Pelee, and in the Great Lakes in general. Of most importance, it provides quantitative data on sediment dynamics for the offshore, as well as the beach zone, for a more complete interpretation of shoreline response on the long-term (annual) and in relation to short-term events (storms). In contrast, most hypotheses regarding sediment transport processes at Point Pelee are based on limited geomorphological data.

Specific objectives include:

(i) An assessment of the annual trends in beach and offshore erosion at Point Pelee from 1974-1981, to determine if the shore is recovering from the excessive erosion conditions incurred during the high lake level period;

(ii) Determination of the relative levels of sediment effecting the beach, nearshore and offshore zones, and the sediment transfer processes involved in the westerly migration of the Point;

(iii) Establishing the significance of offshore dredging operations to the south of Point Pelee in relation to its effect on beach erosion.

1.3 Report Outline

This first chapter of the report provides a brief description of the Point Pelee area and its significance as a major wetland habitat in the Great Lakes. The problem of continuing shore erosion is introduced, along with the concern for the need to resolve what the relative effects of the natural processes are versus activities undertaken by man on the beach dynamics. Objectives of the study are outlined which together are aimed at providing a better understanding of the processes operating in the Point Pelee area.

Chapter 2 provides a description of the Point Pelee setting that includes location, sedimentary zones, offshore morphology, and the lacustrine environment for the region. This is based on previous records and data collected during the monitoring program.

Chapter 3 outlines the methodology involved in the data collection and analysis, and considers limitations of accuracy inherent in the onshore levelling and offshore sounding process. Because of a lack of a universal standard for shore terminology, this chapter also defines the shore zones used for this study.

Chapter 4 provides a brief review of the existing theory concerning processes of shore erosion in general, with emphasis on summarizing the results of previous studies that have investigated shore erosion at Point Pelee.

Chapter 5 presents the results and observations of the profile data collected for the beach, nearshore and offshore zones in terms of annual linear (recession) and volumetric (erosion) changes; short-term adjustments to assess the impact of storms; a sediment budget; and dynamics in general (e.g. interrelationships with process elements). The impact of dredging activities on shore erosion is also discussed.

Chapter 6 presents the summary and conclusions.

2. DESCRIPTION OF THE STUDY AREA

2.1 Physical Setting

The Point Pelee spit, and shoal system to the south of the Point, form part of a cross-lake ridge (Pelee-Lorain moraine) that separates the central and east basins of Lake Erie (Figure 1).

Point Pelee National Park consists of a central fresh water marsh area of 1113 hectares (2751 acres) and a dryland area of about 451 hectares (1115 acres) which for the most part is formed by wooded sand ridges (Parks Canada, 1982). East and west beach ridge formations vary considerably as a reflection of the relative stability conditions. The west beach reaches a maximum height of about 5 m. Dune formations are well wooded, stable and the shore is generally considered to be prograding. In contrast, the east beach is a fragile ridge of sand less than 2 m in height and is subject to breaching during storm conditions. Investigations have been made of the erosion conditions along the east shore that date back to the early 1900's (Kindle, 1918). Since the high lake level conditions of 1973, the beach has remained in what appears to be a state of sediment starvation.

Figure 2 shows the distribution of bottom sediments in the Point Pelee area as reported by Coakley (1972). Underlying the spit and marsh deposits is material of glacial origin that outcrops on both sides of the Point as illustrated in Figure 3. On the east side, this "solid clayey glacial deposit" is exposed at about the 4-5 m depth (Kamphuis, 1972), and from sediment surveys undertaken later by St. Jacques et al (1976), forms a continuous deposit that extends about 15 km offshore. Outcroppings of glacial material on the west side of the Point appear at

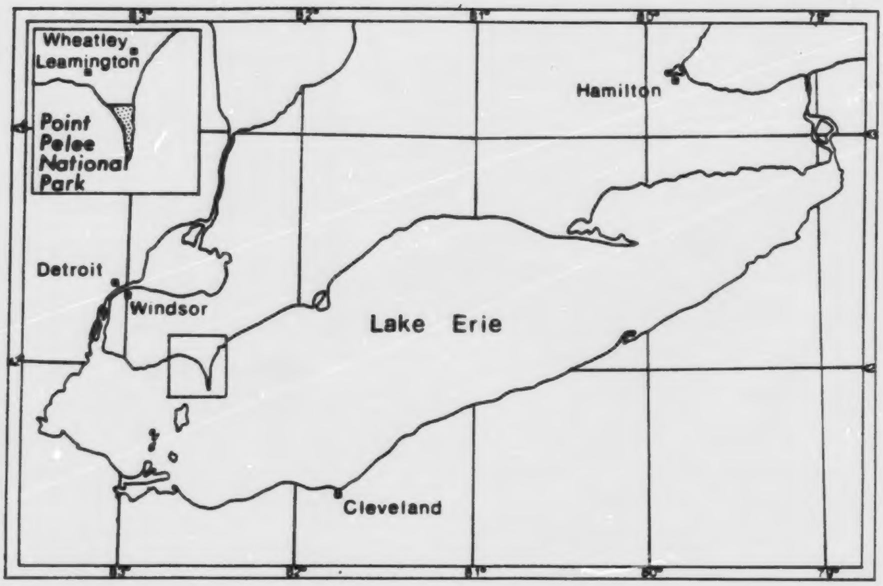
Wheatley
Leamington
Point Pelee National Park
Hamilton
Detroit
Windsor
Lake Erie
Cleveland

Figure 1. Location of Study Area

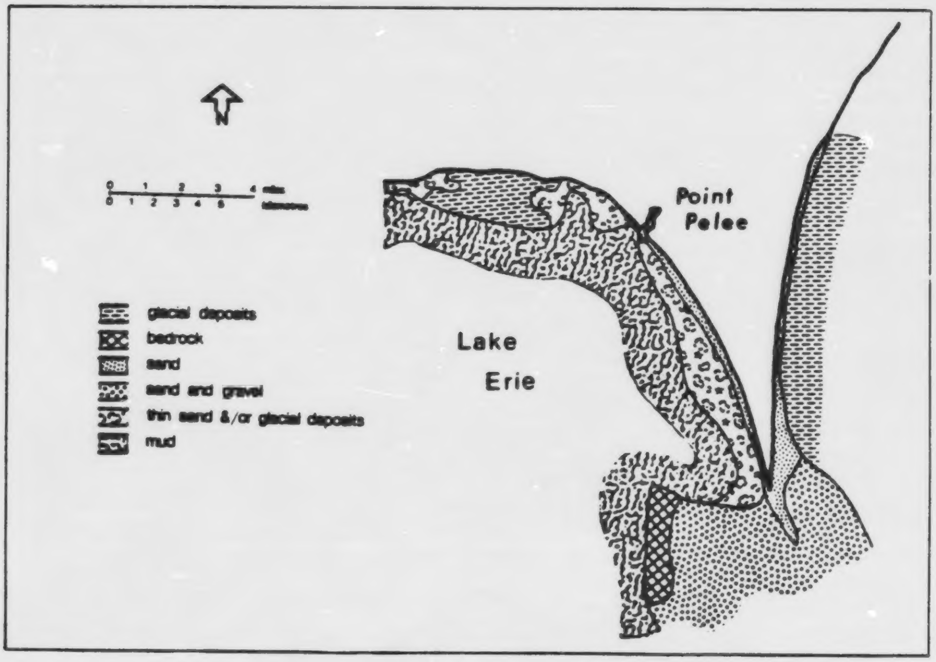
N
0 1 2 3 4 miles
0 1 2 3 4 5 kilometres
glacial deposits
bedrock
sand
sand and gravel
thin sand &/or glacial deposits
mud
Lake Erie
Point Pelee

Figure 2. Offshore Bottom Sediments (Coakley 1972)

greater depths (9-10 m) and are veneered by thin sand. To the south of Point Pelee, sand and gravel deposits exceed 10 m in thickness and form a near symmetrical distribution on both sides of the spit. From the work of St. Jacques et al (1976), there is a definite gradation from coarse to fine sized materials in an eastward direction south of Pelee that suggests currents have played a major role in their distribution.

2.2 Offshore Morphology

Offshore morphology is an important factor in the interpretation of shore processes. For example, the position and development of the submarine bar is a function of the break-point of the wave, the depth of water over the crest of the bar and changing wave conditions (King, 1972). The bathymetry of the offshore also affects the amount of wave energy reaching the shore as a shallow offshore zone causes the waves to break at a greater distance offshore.

The contrast in offshore morphology of the east and west sides of Point Pelee is evident in an initial set of profiles taken at each of the survey sites in June 1984 (Figure 3). The difference in morphology is a reflection of a shoreline that is prograding on the one hand (west side), versus a shore that is eroding on the other (east side).

The west side of Point Pelee is characterized by a relatively featureless offshore zone with smooth uniform slopes except for a general change in slope at an 8-10 m depth where the spit formation rests on the lake bed. Coakley (1972) referred to this feature as the edge of the Pelee rise. The position of the edge of the Pelee rise

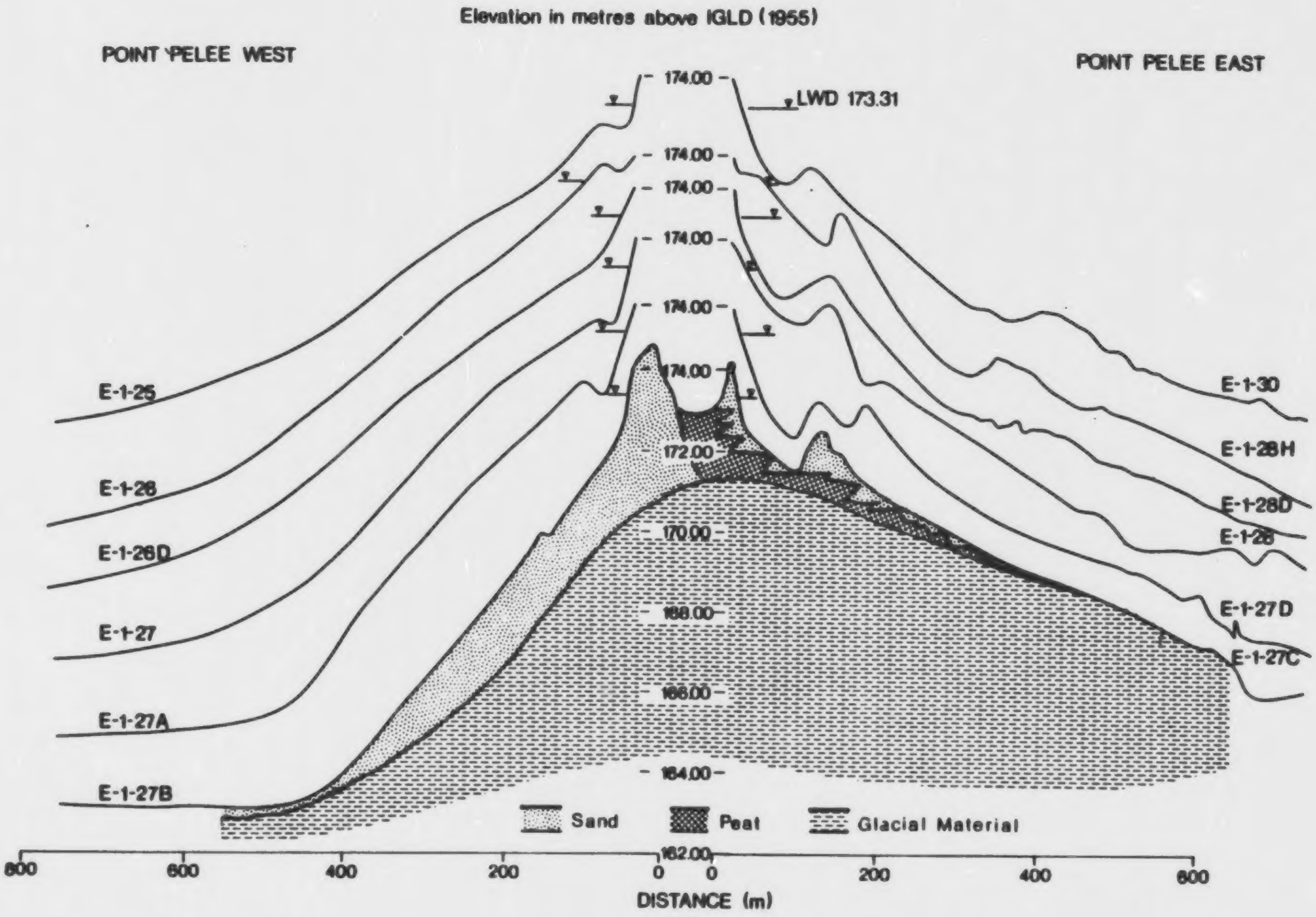
Elevation in metres above IGLD (1955)
POINT PELEE WEST
POINT PELEE EAST
LWD 173.31
174.00
174.00
174.00
174.00
174.00
174.00
172.00
170.00
168.00
166.00
164.00
162.00
E-1-25
E-1-26
E-1-26D
E-1-27
E-1-27A
E-1-27B
E-1-30
E-1-28H
E-1-28D
E-1-28
E-1-27D
E-1-27C
Sand
Peat
Glacial Material
800
600
400
200
0
0
200
400
600
DISTANCE (m)

Figure 3. Offshore Profiles of Point Pelee (With Schematic of Underlying Deposits (Coakley 1972))

tapers in width from about 0.7 km at the base of the Point, to about 0.5 km at the tip. Offshore slopes vary from 1:63 at the base of the Point, to 1:47 near the tip. It is of interest that Coakley reported a "pronounced shoreward advance" (eastward shift) of the Pelee rise from 1964 to 1971, when the Point Pelee landform generally is migrating westward. Coakley and Cho (1972), cited by Coakley (1972), suggest a direct relationship between this phenomenon and abnormally high erosion rates of the shoreline in the vicinity of the advance. Single, discontinuous bar and trough development is evident along the west shore, however, it is usually of small magnitude (e.g. <0.5 m) because of a limited wave regime.

The bathymetry of the east side of Point Pelee contrasts dramatically with that of the west side. Development of multiple inner submarine bars and troughs occurs at greater depths (3 m) and are much larger than their western counterpart. This is in response to a storm wave environment that develops over a fetch distance of 200 km. The edge of the Pelee rise on the east side is not distinguishable, however, sand deposits end at about the 4 m to 6 m depth. The inner foreshore slope is similar to that of the west side (1:55) above the 4 m depth. Beyond this depth, the slope flattens out to about 1:144. Coakley (1976), interprets this terrace-like feature as a possible wave-cut abrasion ramp in the gently sloping glacial till material and as further evidence of a general westward migration of the Pelee landform.

To the south of Point Pelee, the offshore bathymetry is an undulating and hummocky surface consisting of a number of linear crests and troughs of random orientation. Of particular importance to this study (because of the implications to the sediment budget), is a 10 m deep trench that lies about 3 km south of the tip. Because its origin may be related to past dredging activities, and the fact sediments in this area are thought to be an important factor in the supply of sediments to the beaches of Point Pelee, dredging has been viewed recently as a potential negative factor in the sediment budget of the Point.

2.3 Lacustrine Climate

At Point Pelee, the elements of waves, currents and lake levels are primarily responsible for the dynamics in offshore morphology. Because of the position of the Point Pelee landform near the western end of Lake Erie, and the way that the Point extends into the lake, the west and east shores are exposed to very different lacustrine conditions. The west shore of Point Pelee is exposed to prevailing westerly winds, and the east shore to storm winds from the east.

2.3.1 Wind and Wave Climatology

Fetch is the overwater distance that wind travels in generating a wave spectrum. At Point Pelee, the different fetch distances affecting the west and east shores are a major factor in the realm of shore processes, as the maximum effective fetch (effective fetch takes into account the limiting effect of the width of the lake basin (U.S. Army Corps of Engineers, 1973)) for the east side (138 km) is nearly three times that of the west shore (50 km) (Skafel, 1975)) This results in significantly more wave development during storm conditions when winds are from the east, and abnormally high lake levels due to wind set-up conditions.

According to information presented in Garriott (1903) and

Richards and Phillips (1970), the most severe weather conditions occur during the months of March, April, November and December. High winds in excess of 29 km/hr occur 54%-58% of the time during the spring months and up to 66% of the time during November and December. The predominant direction of high winds during these storm periods is from the west and east on a 50/50 basis during the spring, and primarily from the west during late fall and early winter. Because wind direction during these periods approximates the longitudinal axis of the lake, these periods are also the most destructive, particularly under "noreaster" conditions.

Most descriptions of the wind/wave climatology in Lake Erie refer to Richards and Phillips (1970) who present monthly wind frequencies [and hindcast wave heights] for Lake Erie based on a conversion of wind data collected at London, Ontario, to over-lake conditions for the period 1957 to 1966. Saville (1953) also provides wave climate information for various locations along the south shore of Lake Erie using standard hindcast methods.

Using the monthly wind climatology developed by Richards and Phillips (1970), Skafel (1975) applied standard hindcast techniques to describe wave characteristics for each of the seven fetch lengths at Point Pelee under a variety of wind conditions. Maximum significant wave heights for the west shore range from .3 m to 1.4 m with corresponding periods of 2.20 seconds to 4.35 seconds for wind speeds of 15 km/hr and 70 km/hr, respectively. For the same wind speed classes, maximum wave heights for the east shore range from .3 m to 2.2 m with corresponding periods of 2.61 seconds and 5.65 seconds. Under similar storm conditions, the east shore is exposed to significantly higher and longer waves than the west shore.

Under strong northeast winds and with fetch distances of up to 138 km, intense wave activity is directed toward the east shore with deep-water significant wave heights reaching maximum hindcasted values of 8 m (Richards et al, 1970). However, Coakley and Cho, (1972) (cited in Coakley et al, 1973) indicate that average values for waves reaching the beach bar under these conditions are less than 3 m. Coakley et al (1973) indicate that during the storm of November 13-14, 1972, with winds peaking at 76 km/hr, the highest significant wave was 4.1 m, with a probable maximum wave height of 6.4 m.

Wave measurements have been undertaken at Point Pelee, but only on a short-term basis. The results of these data when compared to hindcasted values, indicates that the hindcast values underestimate measured wave heights by up to 50% (Shaw, 1978).

2.3.2 Lake Levels

Lake level fluctuations are an important factor in shore processes as they determine the elevation that waves impact on the beach berm and the depth at which waves affect the lake bottom. Under certain conditions, changes in lake level are particularly important at Point Pelee as they create strong hydraulic currents around the tip of the Point and contribute to the formation of breaches in the beach berm.

Long-term changes in lake level are primarily the result of variations in natural factors such as precipitation, evaporation, runoff, storage capacity of the lakes, and outflow through interconnecting channels. Although a number of attempts have been made to establish the recurring periods of highs and lows as a cyclic phenomonon, the changes in levels can be considered random (Ministry of Natural Resources, 1981).

Based on the period of record since 1860, water levels have fluctuated between a low of 173.0 m above International Great Lakes Datum (IGLD) in 1935, and a record high of 174.8 m (IGLD) reached during the high water stage in 1973 (Figure 4).

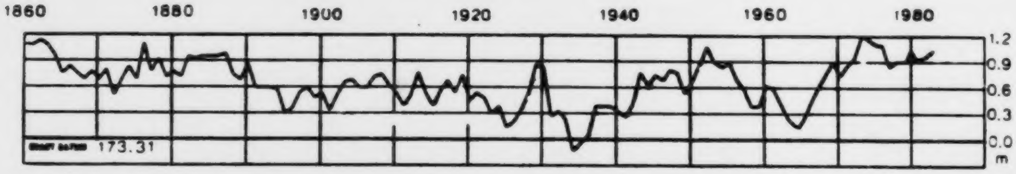

Figure 4. Hydrograph of Lake Erie Annual Mean Lake Levels

In examining the historical record of water levels on Lake Erie, Coakley (1976) found that lake levels have been below the median value of the two extremes (173.9 m), as much as they have been above. He further compared stages of water level to rates of erosion and found that there was no consistent relationship between shoreline change and lake level stage, as the west side continued to show slight accession during the same period that the east side was eroding (Coakley, 1976). However, he suggests that the "net rate" of shoreline change is sensitive to changes in lake level, as rates of erosion and accretion were higher during rises in lake level or high water stages.

Because Lake Erie is relatively shallow, and has its longitudinal axis in a general east/west orientation, under strong wind conditions the surface of the lake tilts to produce what is called a wind setup. A wind setup is the difference in elevation of the lake's surface from one end of the lake to the other. Platzman (1963) and Saville (1953), (both cited in Coakley et al 1973), indicate setups have exceeded 3.7 m at least four times during a 20-yr period, with a maximum of 5.5 m.

At Point Pelee, the setup would be less than the extremes cited above because of the shorter fetch lengths involved. Coakley, Haras and Freeman (1973), for example, indicate a rise in lake level of about .6 m along the east shore as a result of a storm surge that took place at Point Pelee in November, 1972, when winds reached 76 km/hr. When combined with a high lake stage, storm waves that may be in excess of 4-6 m, overwash the beach berm as shown in Figure 5.

A periodic short-term fluctuation in lake level (seiche) also occurs on Lake Erie where the surface of the lake oscillates with a period of about 14 hours (I.A. Hunt Jr., 1959). A seiche in the Great Lakes is usually caused by an abrupt change in barometric pressure, or from a return surge wave as a storm subsides as a result of diminishing windspeeds or a shift in wind direction from the major axis of the lake. Figure 6 shows this characteristic seiche for Lake Erie, and a setup that occurred as a result of a storm from the northeast with winds of up to 43 km/hr. In this case, the setup and seiche combined for an overall rise in lake level of about 50 cm above the previous daily mean (Shaw, 1978).

The morphology of the Point Pelee spit and shoal, in separating the central and west basins of Lake Erie, is such that during setup

Figure 5. East Beach Under Overwash Conditions, April 1974
(photo credit: D. Wigle, Point Pelee National Park)

conditions, in particular, the hydraulic flow between the two basins is restricted because of the impediment to flow that the cross-lake ridge system creates. This results in a piling-up of water on the windward side of the Point, and a setdown or drop in water level on the leeward side. With prevailing westerly winds, the hydraulic gradient is generally from west to east. Figure 7 shows an example of a 20-26 cm difference in water levels between the east and west sides of the Point that was sustained over a four-day period under moderate west winds. Maximum gradients are reported to exceed 60 cm (Shaw, 1978).

The difference in water levels between the west and east sides of Point Pelee produce distinct current flow characteristics around the Point, and are a major factor in the mechanics of sediment transfer within the spit and shoal budget.

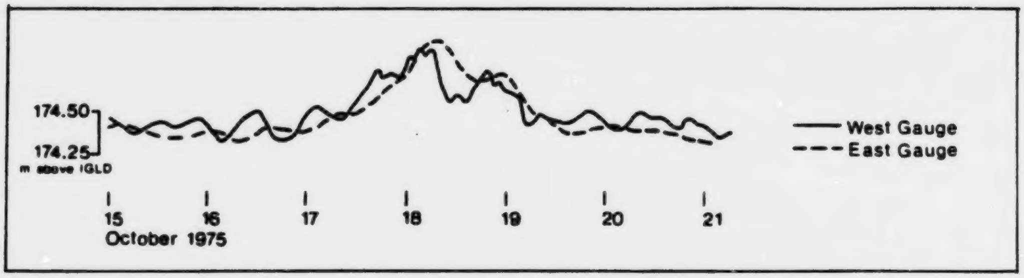

Figure 6. Water Levels for the West and East Sides of Point Pelee During a Storm from the Northeast (Shaw 1978)

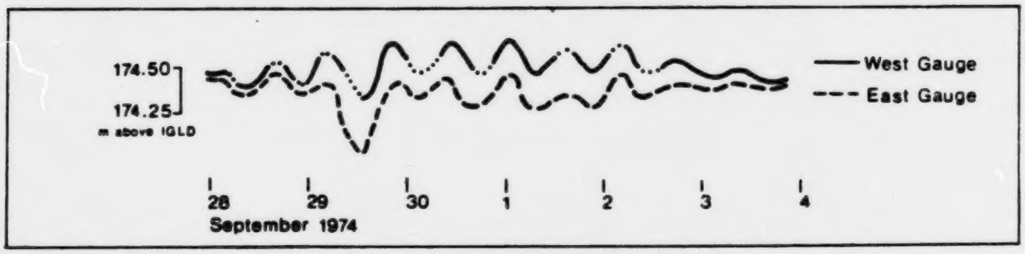

Figure 7. Water Levels for the West and East Sides of Point Pelee During Moderate Westerly Winds (Shaw 1978)

2.3.3 Lake Currents

Because of the hazards that strong currents presented to the early navigator of the Great Lakes, descriptions of lake currents in the vicinity of Point Pelee are found in early historical navigation records and observations made by commercial fishermen. Kindle (1933) provides a summary of some of these earlier accounts that were taken under varying lake conditions. He reported that current speeds ranging from 43-80 cm/sec occur on both sides of the Point, and that they are generally in a southward direction. Anomalies such as flow oscillations, reversals and excessively strong flows of up to 134 cm/sec off the tip of the Point were also noted.

Later, Turnbull (1963) reported from information given in a Report of the Ontario Select Committee on Lake Levels and from local observation, that there is a general northerly drift on the west side, and a general southerly offshore drift with a northerly inshore drift on the east side. He further noted littoral drift reverses, and that there is an overall net drift from south to north on both shores.

More recent information derived from insitu current meters and drogue measurements provide further detail on the flow characteristics at Point Pelee. Bottom currents were measured on a continuous basis off the west and east shore, and to the south in the vicinity of the area formerly licenced for dredging, during part of this study. In the preliminary report, Shaw (1978) indicates that for the period of record (1 month), the average speed (15 cm/sec) for bottom currents on the west side was three times that of the other monitoring locations, and that it was predominantly in a northerly direction parallel to the shore. A seiche current predominated at the same depth (4 m) on the east side, and in the shoal area to the south of the Point, in direct response to Lake Erie's oscillating surface. The relationship between lake level fluctuations and current flow at the other two current meter locations is also evident but to a lesser extent.

Maximum currents recorded during the survey ranged from 40-68 cm/sec. However, these are not representative of currents under high energy conditions as instrumentation problems were encountered during storm activity. Nevertheless, periods of high current speeds generally corresponded to flows toward the north. This fact becomes particularly important to the sediment budget of the Point Pelee shores, as it is under these conditions that the extensive shoal deposits to the south of the Point would potentially become a source of sand to the beach and nearshore zones.

Drogue movements taken at 1 m and 5 m depths tended to confirm the irregularity of Pelee currents noted above, in addition to an inshore counter flow to the south current on the west side of the tip of the spit. Coakley and Cho (1972) observed current reversals at the tip of the Point on the west side (about 60% of the time), and Bukata et al (1975) refer to this backflow as common elements in the "mirror-image" model for the evolution of the Point Pelee and Rondeau landforms.

2.3.4 Ice

Rondy (1971) developed a series of ice charts for Lake Erie that shows a characteristic pattern and extent of ice cover under varying winter conditions, Figure 8. Generally, the east shore is exposed to open water conditions under mild and normal winter conditions, with open to close pack ice (.4-.9 coverage) in parts of the central basin. Consolidated pack ice only forms in the central basin under severe winters, or for a short period (2 weeks) during a normal winter when it is mixed with close pack (.7-.9 coverage). In contrast, the west shore of Point Pelee generally shows ice cover ranging from close pack to consolidated pack over the entire western basin under mild and normal winters for periods of up to 6 weeks.

The influence of an ice cover as a process element in beach dynamics is generally perceived as a positive one with respect to ameliorating damages caused by wave erosion. The accumulation of shorefast ice forms a temporary shore protective structure that emulates the effect of a revetment in dissipating wave energy. Furthermore, when an ice cover forms over the lake surface, it reduces the area of open water, or effective fetch distance, which limits the development of wind-generated waves. In view of the information presented above, ice conditions may be an important factor in the westward migration of the Point Pelee landform, as the west shore is protected from wave action for most of the winter months.

The dynamics of ice in the shore zone, especially its negative influence, has not been a focus of study to any great extent in the Great Lakes. Exceptions to this include a description of an ice piling event that occurred along a 5 km reach of Lake St. Clair shoreline (Boyd, 1981), and an investigation of the effects of winter processes at Point Pelee (Dickie and Cape, 1974). Although no profile data were collected, Boyd provides an account of the atmospheric and lake conditions that lead to the development of a 5 m high ice ridge over a

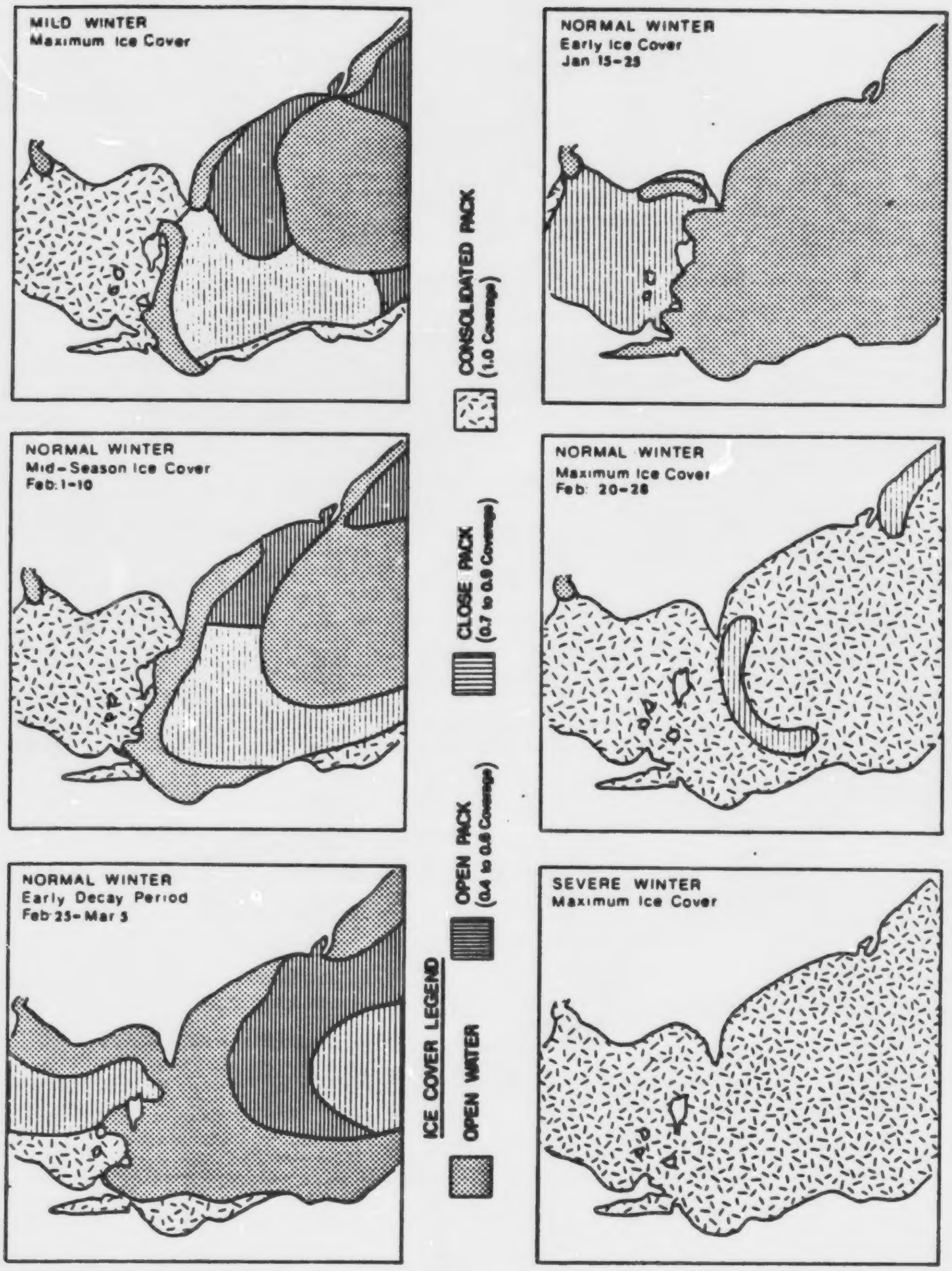
MILD WINTER
Maximum Ice Cover
NORMAL WINTER
Early Ice Cover
Jan 15-25
NORMAL WINTER
Mid-Season Ice Cover
Feb 1-10
NORMAL WINTER
Maximum Ice Cover
Feb 20-28
NORMAL WINTER
Early Decay Period
Feb 25-Mar 5
SEVERE WINTER
Maximum Ice Cover
ICE COVER LEGEND
OPEN WATER
OPEN PACK (0.4 to 0.6 Coverage)
CLOSE PACK (0.7 to 0.9 Coverage)
CONSOLIDATED PACK (1.0 Coverage)

Figure 8. Extent of Ice Cover on Lake Erie During Mild, Normal and Severe Winters (Rondy 1971)

20 min. period and the damages incurred as a result of its shoreward advance.

The effects of winter processes at Point Pelee were investigated by the University of Windsor through the winter of 1973 - 1974, (Dickie and Cape, 1974). They found that although the east beach was protected by a series of stable ice ridges of up to 6 m in height, storm waves caused an overall steepening of the beach face making it more vulnerable to erosion, and that most sediment transfer occurred during ice break-up in early spring, e.g. under north-easterly storm activity. In contrast, the west side of Point Pelee was said to have built-up over the winter as a result of sediment being transferred around the tip of the Point.

Similar observations were made during the first winter (1974-1975) of this study where the greatest loss of beach material occurred during the period between the late fall and spring surveys (Shaw, 1978). Average profile loss of beach material from the east shore was 18 m^2/m. As with the previous winter survey by the University of Windsor, the west side built-up an average of 4 m^2/m.

3. METHODOLOGY

3.1 Data Collection

Under a Canada/Ontario Agreement to monitor shore erosion throughout the lower Great Lakes shoreline, the Shore Properties Studies Section of the Ocean Science and Surveys Branch, Department of Fisheries and Oceans, Burlington, Ontario, began shore erosion surveys at two sites in Point Pelee National Park in 1973. Because of the interest of Parks Canada in supporting the monitoring program at Point Pelee, especially at a time when Park beaches were undergoing excessive erosion, the number of survey sites was increased for better representation of the reaches of shoreline within the Park.

Survey sites were established to monitor shoreline changes from the base of Point Pelee to the tip of the spit. Six stations were set up on each side of the Point, in addition to 6 spoke profiles that run radially from a fixed point at the tip. These monitored changes to the treeless tip of the Point and the offshore shoal to the south. Because of the high erosion rates affecting the east shore, some survey sites had to be re-established while another 5 survey sites were added to monitor critical reaches of shoreline. Figure 9 shows the full complement of monitoring sites.

The network of survey sites was established with a traverse around the perimeter of the Park. Where possible, each site was tied into fixed landmarks for quick reference, and temporary benchmarks were

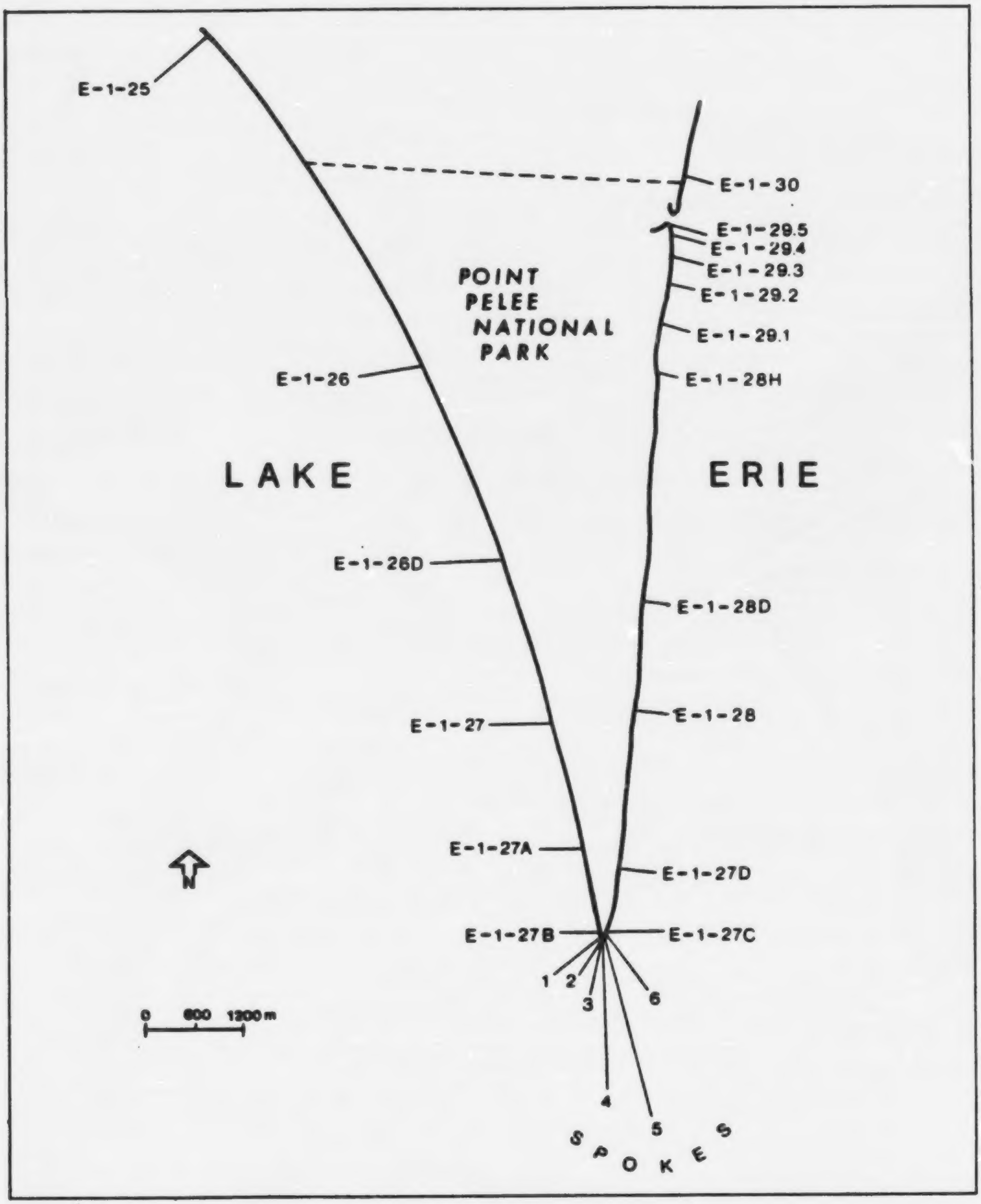
E-1-25
E-1-30
E-1-29.5
E-1-29.4
E-1-29.3
E-1-29.2
POINT PELEE NATIONAL PARK
E-1-29.1
E-1-26
E-1-28H
LAKE
ERIE
E-1-26D
E-1-28D
E-1-27
E-1-28
E-1-27A
E-1-27D
N
E-1-27B
E-1-27C
1
2
3
6
0 600 1200m
4
5
SPOKES

Figure 9. Erosion Monitoring Stations at Point Pelee National Park 1974-1981

established at each station for vertical control.

Conventional topographic surveying methods were used to profile the onshore section of the beach that extended from the origin of the survey line to about a 1 m depth. The offshore section of the profile was obtained using hydrographic survey methods. A small powered survey launch equipped with a continuous depth recording echo sounder (Raytheon, Model DE-719) continued the profiling from where the topographic survey ended, to the outer limit of the offshore profile. Positioning and maintaining the survey launch on-line required continuous directional guidance. This was achieved using electronic distance measuring equipment (Tellurometer Hydrodist), and a transit in conjunction with two-way radios.

Surveys were conducted 4 to 5 times from April through November in 1974 and 1975. The number of surveys was reduced during subsequent years to 1 to 3 times annually, largely on account of field party cuts and budget restraints.

In order to ensure reliability of the data, checks for accuracy were conducted in the field by closing on the benchmark at the end of each onshore survey, and by calibrating the sounding equipment at the beginning and end of each sounding day using the standard bar check method.

Current measurements (using insitu electromagnetic current meters and tracking drogues), wave heights (provided by DOE) and bottom sediment data (Ponar Grab samples) were also collected during the initial years of the survey program. Results from these data were presented in an earlier report (Shaw, 1978).

3.2 Data Analysis

Onshore survey field notes were reduced to establish the profile coordinates using the temporary benchmarks established at each profile site which enabled direct comparison of the series of profile data. Sounding charts were reduced based on hourly lake level information provided by water level gauges in the area. Once the water level information was established for the time of the survey, the sounding chart was digitized to determine the series of coordinates in defining the shape of the bottom profile. The coordinates were then used in conjunction with computer programs (Weaver, 1982) to develop profile plots and volume calculations.

3.3 Limits of Accuracy

The reliability of the profile data is affected by a number of factors, least of which is the accuracy limits of the instrumentation. More important are factors such as the experience of the survey crew and their understanding of the survey objectives, and environmental conditions such as lake surface and bottom characteristics.

The Point Pelee surveys were generally undertaken by a crew of four, two of which were continuing employees who participated in the survey each year. This ensured a continuity of survey methods and standard field checking methods that were routinely carried out to ensure reliability of the survey data. The potential for error due to rough lake conditions was controlled somewhat by the fact that offshore surveys were only undertaken when lake conditions were relatively calm, due to safety considerations. In addition, the Pelee setting provides for optimum survey accuracy with smooth offshore profiles and low, narrow beaches.

Shaw (1978) indicates accuracies for the onshore portion of the profile at Point Pelee to be estimated within .03 m vertical and .05 m horizontal. He also reports on the results of repeatability tests for offshore accuracies that indicate a spot depth standard deviation of .09 m, and a deviation of 1.2% from the mean for the calculation of the total area under a given datum. Using the same equipment, but at a different location in the Great Lakes, Boyd (1981) reported a deviation of .8% for the mean area calculation.

The reliability of the offshore data is affected significantly by the distance from shore and depth of water due to sounding errors and boat positioning errors (Komar, 1983). In order to compensate for these kinds of errors, a "closure depth" was applied to each profile beyond which the bottom presumably does not adjust to surface wave or current conditions. For this study, the closure depth corresponds to the outer limits of the sand deposits and was derived from profile interpretation, and information provided in the nearshore sediment studies of Coakley (1976), and St. Jacques and Rukavina (1976). This assumes that the glacial clays that extend beyond the sand deposits fringing Point Pelee are relatively stable. As such, the elevation of the clay provides vertical control similar to the benchmark of the onshore surveys, providing for much more reliability of the offshore data.

Comments regarding limits of accuracy are also discussed in Chapter 5.

3.4 Terminology

Because of the difference of opinion in the literature about nomenclature used in defining the coastal zone (Hails, 1974), it is necessary to clarify the terms used in this study for sub-dividing the shore. The terms used are similar to those found in King (1972) and Ministry of Natural Resources (1981), but have been modified to better reflect the Point Pelee environment and the objectives of this study. Limits of accuracy were also a factor in determining the shore zones used in this study.

The Point Pelee shore is sub-divided into 3 zones. The "beach" zone is the unvegetated sand ridge or berm that is most used to diagnose the condition of the coastal zone, as it is the most visible. The beach corresponds to the portion of the shore profile that was surveyed using topographic survey methods. It extends from the vegetation line or some other inland stable reference point, lakeward to about the 1 m depth (174.0 m above International Great Lakes Datum 1955 (IGLD).

The "nearshore" zone extends from the 1 m depth to the outer limit of the area of submarine bar development. It is defined by an upper limit elevation of 174.0 m (IGLD), and a lower limit elevation of 171.0 m (IGLD). This zone is generally described as the most dynamic of the shore zones in that it is the area directly affected by nearshore currents and breaking waves.

Beyond the nearshore zone is the "offshore". It extends from the outer limits of the nearshore zone (elevation 171.0 m (IGLD), to where the sand deposits thin out at the edge of the Pelee rise (closure depth).

The beach, nearshore and offshore zones are shown schematically in Figure 10.

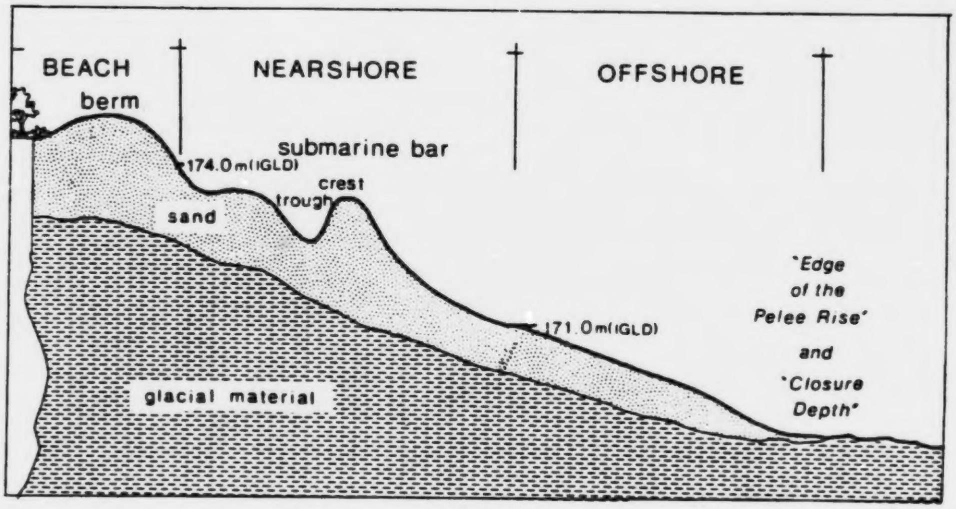
BEACH
NEARSHORE
OFFSHORE
berm
submarine bar
174.0m(IGLD)
crest
trough
sand
'Edge of the Pelee Rise' and 'Closure Depth'
171.0m(IGLD)
glacial material

Figure 10. Terminology of the Point Pelee Shore Zone

4. EXISTING THEORY

4.1 The Study of Shore Processes in the Great Lakes

It is not the intent of this thesis to provide an overview of shore processes in general, as the subject is covered comprehensively in a number of existing books. Most noteworthy examples are "Beaches and Coasts" by C.A.M. King (1972), "Processes of Coastal Development" by V.P. Zenkovich (1967), "Handbook of Coastal Processes and Erosion" by P.D. Komar (1983), and the "Shore Protection Manual" of the U.S. Army Corps of Engineers (1973). Rather, this section presents a brief review of the research activities that have been taking place in the Great Lakes shore zone, with particular reference to the Canadian literature. It also discusses some of the factors that are limiting the advancement of the knowledge of shore processes in Canada, based on personal observations and views expressed in the literature.

Boyd (1979) provides a chronological review of the literature concerning shore processes of the Canadian shoreline of the Great Lakes from the mid-eighteenth century to the present. Early works dating to the turn of the century, provide some useful baseline data and supplementary information, in addition to mostly qualitative reports of lacustrine processes such as seiches, sediment transport, currents and ice. Quantitative research in shore dynamics is not evident in the Great Lakes literature until the 1950's. This was a period of rising lake levels and active shoreline landuse development. Collectively, Canadian and U.S. studies provide detailed examinations on various aspects related to Great Lakes shore erosion that include geology and shore geomorphology, surges and seiches, littoral transport processes, and bluff erosion.

It was not until the 1970's, that a major effort to gaining a better understanding of processes operating in the shore zone is clearly evident in the literature. According to the Associate Committee for Research on Shoreline Erosion and Sedimentation (ACROSES) of the National Research Council Canada, there were over 400 research projects on the subject of nearshore processes underway in Canada between the years 1976-1982. The need for increased communications among the scientific community is also apparent in the 1970's, as ACROSES was created to promote communications on aspects of national research in nearshore processes. Annual conferences address coastal protection and modelling, field investigations and measurements, waves, and nearshore dynamics. ACROSES also holds specialty workshops to address particular areas of research such as the Workshop on Ice Action on Shores (1981). The interest in the shore zone during the 1970's is even more apparent in the U.S. where the American Society of Civil Engineers (A.S.C.E.). initiated a number of specialty conferences on topics such as wave dynamics (WAVES '74), modeling (MODELING '75), shore protection and sediment transport processes (COASTAL SEDIMENTS '77), and structures in the shore zone (COASTAL STRUCTURES '79).

Not only was this a period of increased research and monitoring activity in the shore zone, but it is also evident from a review of the literature, that researchers and shore managers were beginning to communicate through open forums for the integration of science into coastal zone management strategies. The U.S. was particularly active in this regard, as evidenced by the number of annual symposia initiated during the 1970's for the express purpose of promoting multidisciplinary communications. The American Society of Civil Engineers, for example, began a series of coastal and ocean management meetings in 1978, which address the interrelationships of the environmental, socioeconomic, engineering, and regulatory aspects of coastal zone management, e.g. "Coastal Zone" symposia of 1978, 1980 and 1983. A number of books also appeared on the subject about this time such as COASTAL RESOURCES MANAGEMENT by R.B. Ditton et al (1977), COASTAL WATERS - A MANAGEMENT ANALYSIS by J.M. Armstrong et al (1978), and COASTAL ECOSYSTEM MANAGEMENT by J. Clark (1977).

In Canada, a special Shore Management Symposium was held by the Canadian Council of Resource and Environment Ministers (1978) that was to focus national attention on the sensitivity of the shorezone and to develop management guidelines. A major program was underway in the Great Lakes during the 1970's under a Canada/Ontario Agreement to follow-up the recommendations of the Canada-Ontario Great Lakes Shore Damage Survey Technical Report (1975). This culminated in a number of technical publications to assist the shore manager in developing shore management policies, such as the Coastal Zone Atlas (1975), 100-year Flood and Erosion Prone Area Maps (1978), an evaluation of erosion rates and processes (Boyd, 1981), a Shore Management Guide (1981), and a series of public information brochures.

In spite of considerable progress in our understanding of nearshore sediment dynamics, very little is known about shore processes operating in the Great Lakes, relative to the knowledge available concerning processes affecting marine coasts. In his review of some current trends in nearshore research, Hails (1974) states that the biggest problem, "is simply the collection of data for a sufficiently ong period to gain a representative picture of the changes taking place n the coastal zone." This problem is particularly evident with respect o the Canadian shore of the Great Lakes, where the long-term commitment f funds and a continuity of personnel to monitor shore processes over a omplete lake level cycle, have never materialized.

In a review of the literature concerning shore processes of the reat Lakes, Boyd (1979) reports that major government studies initiated n Canada generally are done only in response to extremes in lake level, when extensive shore damages are incurred. Further limiting the lue of this approach, however, is the fact that this research is rminated when lake levels return to the norm, rather than continuing r a complete lake level cycle. A recent example is the Canada /Ontario reement to monitor shore erosion throughout the erodible portion of e Great Lakes that began during the high lake levels of the 1970's. though the signed Agreement covered monitoring for a 5 yr. period, the ientific basis upon which the program was derived, called for nitoring to extend to the next high water period (Haras-personal mmunication). This would have provided the data base needed to amine the interrelationships of the shore's response to the full range f stages in lake level, as well as the effects of a falling and rising ke level. Because of government budget restraints and other research iorities, the monitoring program Agreement was cut in 1981. As a sult of this discontinuity of research, our knowledge of shore ocesses is limited to pieces of information derived from short-term, te specific studies, rather than having an overall understanding of e cause-effect interrelationships between the geomorphic response of e shore and lake processes. The lack of attention to shore processes, mbined with indiscriminate shore development during the periods of low ke levels, e.g. 1960's, results in record flood and erosion damages being incurred by a new generation facing a new problem.

As a further concern affecting the advancement of knowledge in coastal dynamics in general, Hails (1974) also suggests that restrictive physical factors, limitations of instrumentation, and the fact that most studies are carried out to provide rapid engineering solutions, are factors contributing to the apparent poor correlation between field data and theoretical prediction. The Great Lakes environment is no exception.

4.2 Shore Processes at Point Pelee

It is evident from the literature that shoreline erosion has been a concern at Point Pelee at least since the early 1900's. At that time, erosion of the Point was a potential threat to the safe anchorage of vessels during storms. Although, the basis for this concern has differed over the years, it has lead to numerous inquiries to determine the causes of erosion, and possible solutions. In spite of these efforts, there is yet no clear understanding of the processes effecting erosion at Point Pelee, nor is there evidence that a long-term solution exists.

The main cause of shore erosion reported up until the 1960's, is related to lake levels. Stevens (1917), for example, attributes the high lake levels of 1916-1917 as the most important factor, and Kindle (1918), suggests down-warping of the western basin of Lake Erie to be the initial cause of the disturbance to the stability of the shore zone of Point Pelee. The significance of isostatic rebound as a factor in the erosion of the western basin of Lake Erie also appears in Kamphuis

(1972) and Coakley et al (1972). The influence of water levels continued to appear in reports as a cause of erosion, but it soon became apparent that periodic fluctuations in water level alone are not a decisive factor in trends of erosion at Point Pelee, as erosion is shown to take place regardless of lake level stage (Jarlan 1966, Coakley 1977). In fact, it is suggested that erosion occurring at distances further offshore during a low lake level stage is significant to the overall recession of the Point, as the full effect does not become apparent until the return of high lake level conditions (Persson, 1964).

Another aspect of water level fluctuations (peculiar to Point Pelee) that augments the erosion process, is the difference in water levels between the east and west sides of the Point. Water levels have been observed to vary by as much as 0.6-0.9 m under easterly winds (Jarlan 1966, Coakley et al 1973) and 0.6 m under prevailing westerlies (Shaw, 1978). The Point Pelee spit and island system that forms the divide between the central and western basins of Lake Erie, restricts the backflow of water under storm surge conditions which results in the water piling up on the windward side of the Point. Excessive erosion takes place under these conditions as a result of a superficially raised water level and wave height that combine to completely inundate the low lying east berm (Coakley et al, 1973), and the intense littoral currents that develop as a direct result of the hydraulic head (Jarlan, 1966).

Water level differences between the marsh and lake have also been noted to be a factor in the erosion process, but one which has not been studied in any detail. Chrysler and Lathem (1974) estimate that for a specific reach of shoreline at Point Pelee, flow through the beach berm is on the order of 300 gpm with a head of 0.6 m.

It was not until the 1960's and 1970's, particularly when more field data were collected on sediment distribution and transport mechanisms, that further insight is provided on the dynamics of the shore zone at Point Pelee. Up until this time, current directions were said to be predominantly toward the south which corresponded to the earlier theories of the Point's formation. The difficulty in determining current directions prior to the use of the current meter was noted by Jarlan (1966). He indicates it was not possible to define any particular current direction because of variable winds. Kamphuis (1972) also found radically different current patterns for normal and stormy wind conditions which prevented a clear understanding of the process relationships.

Recent observations indicate that the predominant direction of littoral currents on the west side is toward the southwest, with a backflow current at the tip (Coakley et al 1972, Coakley 1972, Coakley et al 1973 and Bukata et al 1974). Currents on the east side of Point Pelee tend to be more variable. Kamphuis (1972) notes these to be generally from south to north and that longshore current velocities are insensitive to the angle of the breaking wave. Coakley et al (1972), on the other hand, found currents to vary with wave height and angle of the breaking wave, with maximum velocities recorded at angles of 30°- 40°. Reversals in current direction on the east side are also noted by Skafel (1975), Bayly (1977) and Shaw (1978).

It was the information provided by continuous recording current meters that was primarily responsible for the new hypotheses of sediment transport and sources of sediment. The most popular hypothesis for the source of sediments feeding the beaches and shoal at Point Pelee, is reported to be the eroding bluffs, in particular those to the east between Wheatley and Port Crewe (Kamphuis 1972, Bukata 1974, St. Jacques et al 1976, Coakley 1977, Bayly 1977 and Trenhaile et al 1978). With information gained from current measurements and sediment analyses, temporary offshore storage areas were also identified to the south of the Point (shoal) (Kamphuis 1972, Shaw 1978 and Coakley 1977,) and offshore Sturgeon Creek on the west side (Coakley 1977). In fact, Kamphuis (1972) indicates that the shoal acts as a feeder beach for most of the year based on his interpretation of the currents which he suggests flow primarily toward the north.

New hypotheses on the evoluton of Point Pelee were also advanced as a result of sediment and current information that challenged the more conventional mode of spit formation involving converging littoral currents as proposed by Kindle (1918 and 1933), Jarlan (1966) and Kamphuis (1972). Coakley (1976), suggests that as post-glacial lake levels rose, the Point evolved as the result of progressive erosion of a much larger relic feature forming part of the Pelee-Loraine moraine. In accordance with Coakley's theory, Trenhaile and Dumala (1978) suggest that longshore transport was not significant in the initial development of the Point. However, they conclude that longshore transport became the dominant process during the past 1,000 years, as sediment analysis of dune and beach ridge formations (on the west side of the Point) indicate they were built from sediments eroded from bluffs to the north. Using satellite imagery, Bukata, Haras and Bruton (1974) developed a "mirror-image" model for the evolution of Point Pelee and Rondeau landforms involving a bifurcated longshore transport system along the north shore of Lake Erie. Backflow currents around the tips of the spits, according to the model, are responsible for the building-up of the series of parallel beach ridges at each of the peninsulas.

The dynamics of the shore zone of Point Pelee also have been monitored over the years, especially since the accelerated erosion of the east beach in the 1970's. Measurements of shore adjustments are either expressed in linear terms (recession or accretion), or in terms of volume (erosion and deposition). Turnbull (1963), provides the first indication in the literature that erosion is a trend at Point Pelee, and not just a random occurence from year to year, when he notes that the tip of the Point is retreating northward as a result of an unspecified diminishing source of sediments. Up until this time, there is no explicit indication in the literature that erosion was perceived to be a particular threat to the Point as a whole, in spite of the Point's "westward migration" noted by Kindle (1918 and 1933).

Historical and recent rates of recession tend to confirm the relative stability of the west shore and the trend of erosion on the east side. Coakley (1977) indicates a northward retreat for the Point as a whole at a rate of 2.5 m/yr and a westward migration of .25 m/yr, since its formation about 4,000 years ago. Recession on the east side since 1918 is indicated to be greater than 3 m/yr. Other observations showing a westward migration, include those of Persson (1964), Jarlan (1966), Kamphuis (1972), Coakley et al (1972), Coakley (1972), Coakley (1973), Bukata (1974), Coakley (1976 and 1977), Shaw (1978) and Trenhaile (1978). Measurements of erosion also provide an indication of the relative rates of westward migration for the beaches of the Point, with erosion from the east shore being equivlent to 5 times the volume of material being gained by the west shore (1974-1975) (Shaw, 1978).

With the monitoring of the submerged portion of the beach profile at Point Pelee in the 1970's, more was being learned of the dynamics of the nearshore zone. Sand deposits have an outer limit at about the 5 m depth on the east shore (Kamphuis 1972, Coakley 1972), and at about the 10 m depth on the west side (Coakley 1972). Beyond this outer margin of sand is glacial clay (Kamphuis 1972, Coakley 1972). The offshore limit of sand provides an indication of the extent where most of the nearshore response could be expected. For example, Coakley et al (1973) found that nearshore erosion increases shoreward of the 6 m depth on the east side. In an apparent contradiction to observations of westward migration, Coakley and Cho (1972) note that the western edge of the Pelee rise (base of the offshore slope at about the 10 m depth) had regressed several hundred meters during the period between 1964 and 1972. They further note that the extent of the regression corresponded to a reach of shore that had been eroding.

The impact of storms on the beach and nearshore zones was also quantified, particularly following the damages incurred during the high water period of 1972-1973. Under the combined influence of wind setup and storm waves, the east berm receded up to 11 m (Coakley et al 1973, Lavalle 1983). As an indication of the slow rate of beach recovery, (Kamphuis, 1972) notes that more material is transported (south) from the east shore in a few hours, than what is returned (from the shoal) in months. Furthermore, Coakley et al (1973) report that the volume of erosion that took place during an easterly storm (5.5 m^3/m), was 6 times the volume of material which had accumulated over the preceding 5 months (0.9 m^3/m). At this rate of accumulation, it would take a 30 month supply of material for full replenishment.

Accounts of storm damage also provide an indication of the transfer of sediments within the Point Pelee sediment budget. For example, Coakley et al (1973) observed that as a result of an easterly storm, all of the eroded beach material was displaced inland to distances of up to 100 m. Sediment eroded from the nearshore was postulated to have been transported around the tip of the Point and redposited along the west shore. Dickie and Cape (1974) report similar findings. From these observations, westward migration is hypothesized to be related to the transfer of sediment from east to west under storm conditions (Coakley et al 1973).

With what was perceived to be accelerated rates of erosion during the 1970's, the impact of man's interference in the shore zone was being raised as an important issue in the dynamics of shore erosion at Point Pelee. In fact, it was the potential impact of offshore dredging on the stability of the Point that precipitated the initial investigations into the causes of shore erosion in 1917. Dredging was considered to be a negligible factor at that time, as there were no trends of erosion that could be related to it, nor was there any evidence to suggest that the beaches were being supplied with sediments from the shoal under the influence of northerly drift. With the additional information on the sources and transport of sediments, however, recent hypotheses suggest that (under certain conditions) dredging activities could be detrimental to the sediment budget of Point Pelee (Kamphuis 1972, Coakley et al 1972, Coakley 1977 and Shaw 1978). As a result, dredging licences have been suspended indefinitely in the vicinity of Point Pelee since 1974.

Other potential man-made impacts are addressed by Coakley et al 1972, Chrysler et al 1974, Coakley 1977, Bayly 1977 and Shaw 1978, and include nearshore sand mining activities off Port Crewe, Wheatley harbour and shore protection works. Bayly provides photographic evidence showing the progressive erosion to the northeast corner of the Park as a result of a series of groynes installed along an adjacent beach (Marentette Beach). This eventually led to a large breach in the east beach, and reported losses to the Pelee marsh of up to 1.6 ha/day (Bayly, 1977). From this sequence of events, she concludes that it is the currents from the northeast that are responsible for replenishing the east shore. In an investigation of the erosion damages incurred by residents along Marentette Beach, Hudec (1977) suggests a conflicting point of view in that it is the breach that caused the ineffectiveness of the groyne structures fronting Marentette.

In summary, the literature review shows that some of the general concepts regarding processes of shore erosion at Point Pelee, such as westward migration and the significance of post-glacial adjustments in lake level caused by isostatic rebound, continue to be perceived as important elements in the erosion process. It has only been in recent years, with new information on sediments and currents, that further detail has been provided on the processes affecting Point Pelee. This information has led to hypotheses concerning sources of sediment important to the nourishment of Pelee beaches, and new concepts on the formation of the Point. It should also be pointed out, however, that the understanding of shore dynamics at Point Pelee is not at the level to enable accurate predictions or effective control as many of the hypotheses concerning shore processes have yet to be tested.

5. RESULTS AND OBSERVATIONS

In this chapter, a complete record of the shore adjustments for the beach, nearshore and offshore zones is provided in the form of profile plots (Appendices 1 & 2); erosion tables, which quantify shore adjustments in terms of the annual volume of sediment lost and gained; recession tables, that show annual landward/lakeward shifts of the shore; summary tables that provide further statistical information on shore response; time-series plots of the changes in sediment quantities for comparing the response of the shore zones (Appendix 3), and; as a sediment budget, which takes into account reach lengths. The information is presented in terms of averaged annual changes to determine general long-term trends in shore response, and as short-term adjustments in relation to seasonal and storm-related events.

Based on the observations, both the west and east shores of Point Pelee have each been sub-divided into two broad reaches. The WEST SIDE (11.6 km) and EAST SIDE (10.5 km) represent the lengths of shore extending from the north end of the study area, to (but not including) the treeless tip of the spit. The treeless tip of the spit is treated as a separate reach because of its' unique response characteristics. The west shore of the tip is represented by survey stations E-1-27B through to SPOKE 4, and is referred to as the WEST TIP. The east shore of the tip is represented by stations E-1-27C through to SPOKE 4, and is referred to as the EAST TIP. The length of these reaches varies considerably in response to changes in lake level, and large lateral shifts due to prevailing currents. However, they are each approximately .5 km in length. Station locations are shown on Fig. 9.

5.1 Annual Shore Adjustments 1974-1981

5.1.1 Beach Zone

The profile of the beach zone is particularly critical to the stability of Point Pelee, as it is this narrow ridge of sand that acts as a buffer, and a filter, in maintaining the marsh habitat as a separate entity from the lake. The changing condition of the beach profile is illustrated in the series of plots for the area above 174.0 m (IGLD) in Appendix 1. For each survey station, these provide an account of the growth and loss of beach material for the period of record.

West Side and West Tip

It is readily apparent from the profile data that the WEST SIDE of Point Pelee is progressively accumulating more beach material as the area above 174.0 m IGLD, and the width of the beach, are generally increasing with time. West beach profiles gained at an average rate of 1.5 m^2 annually for a westward migration of about 1 m/yr. Time-series plots of sediment volumes (Appendix 3) show that the supply of sediment to the WEST SIDE beach during the survey period was sufficient to mask any losses that occurred as a result of short-term events. Although estimates of beach recovery are affected by the frequency of surveys, trends in beach volume indicate that the time required for full replenishment can be as much as 3-4 yrs., depending on the magnitude of beach material loss. For example, 8 m^2 (or 38% of the recorded beach volume) that was eroded from the beach at station E-1-26 in Nov. 1975, was not fully restored until Sept. 1979. The impact of storms is discussed further in Section 5.2.

An exception to the growth trend of the WEST SIDE beach occurred at station E-1-27, about 2.5 km north of the tip. Changes in volumes of sediment show that this reach of shoreline has periods of erosion and deposition similar in magnitude to that of other stations, however, the net effect is very little over the long-term (e.g. <1 m^2). During the survey period, this reach of shore was in a state of equilibrium whereby the supply of beach material was adequate for maintenance, but not for growth. One explanation may be that the growth areas to the north and south of E-1-27 are nourished by separate sources of sand that were identified by Coakley (1977). In this case, E-1-27 is the southern limit of the sediment transport system for the source offshore Sturgeon Creek to the north, and the northern limit of the sediment drift from the shoal and east side of the Point to the south.

In contrast to the growth of the WEST SIDE beach, data for the WEST TIP beach indicates that erosion predominated during the survey period. Profile plots (Appendix 1) show significant recession of the beach, particularly since the fall of 1979. In comparing the time-series plots for the stations at the WEST TIP (Appendix 3), the response to short-term events appears to be more uniform than what was observed for the WEST SIDE. This suggests that a single continuously active process element, such as currents, may be the predominant controlling factor in the distribution of sediment at the tip.

Volumes of beach erosion (m^2) and recession (m) on the west side of Point Pelee are given numerically in Table 1. This information is based on the average of the measurements taken each year. Stations to the north of the study area (E-1-25 & 26) tend to be least effected by

TABLE 1.

ANNUAL CHANGES IN WEST SIDE AND WEST TIP BEACH PROFILES*

STATION	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81
WEST SIDE EROSION/DEPOSITION (m^2)							
E-1-25	2.8	3.7	1.3	1.3	-1.4	3.6	.9
E-1-26	- .6	-3.1	1.1	1.3	1.9	1.1	2.4
E-1-26D	2.8	5.1	.9	-5.8	3.6	5.4	- .4
E-1-27	1.7	3.4	-6.0	-1.0	- .6	1.1	- .8
E-1-27A	2.5	1.4	8.2	1.5	7.3	1.8	2.5
WEST TIP EROSION/DEPOSITION (m^2)							
E-1-27B	-3.0	-6.1	-1.3	.9	4.3	-22.4	- 4.1
SPOKE 1	-6.3	-3.0	-7.8	.1	1.2	-25.2	(no data)
SPOKE 2	-11.4	-11.4	-5.5	7.5	-6.7	-33.2	(no data)
SPOKE 3	-100.4	87.9	-77.4	46.6	-35.2	-91.0	(no data)
WEST SIDE RECESSION/ACCESSION (m)							
E-1-25	2.3	- .4	0.0	1.9	-2.0	2.1	1.1
E-1-26	0.0	- .5	.4	1.2	1.0	.6	1.1
E-1-26D	2.6	2.0	1.1	-2.7	2.9	1.3	1.5
E-1-27	2.4	.9	-1.2	-3.0	- .7	.7	- .4
E-1-27A	2.9	0.0	7.7	1.0	4.7	.1	.2
WEST TIP RECESSION/ACCESSION (m)							
E-1-27B	- .4	- 5.6	2.4	- .6	.5	-10.9	- 3.9
SPOKE 1	- 4.0	- 1.6	- .4	- .1	.5	-15.3	(no data)
SPOKE 2	-10.1	- 1.5	- 1.6	7.3	- 6.2	-21.8	(no data)
SPOKE 3	-63.0	56.6	-44.8	51.2	-40.3	-56.0	(no data)

* Differences from preceding survey (annual average).
Recession is measured at 174.0 m above IGLD.
Negative values indicate erosion and recession.

shore processes as the maximum average volume change was less than 4 m^2. The magnitude of response gets progressively greater toward the south with maximums of 6 m^2 at E-1-26D & 27, to 8 m^2 and 22 m^2 at E-1-27A and E-1-27B respectively. Extreme values of up to 91 m^2 were recorded at the tip (spoke profiles), however, these are effected by the angle that the survey line intersects the beach. The progressively greater dynamics toward the south is also evidenced in the measurements of annual recession.

A summary of the profile data for the WEST SIDE and WEST TIP beaches is given in Table 2. This differs from the previous information in that it is not based on annual averages. For both recession and erosion, the net change from the initial survey to the last survey is given, as well as the gross linear and volume changes, and the range between beach minimum and beach maximum. Time of minimum and maximum beach volumes are also given. In comparing most parameters, the north to south trend in beach dynamics is evident. Increases to the beach width and volume of the WEST SIDE beach were greater toward the south, as were the losses for the WEST TIP. This trend is also apparent for the gross volume and ranges from minimum to maximum profile. The larger volumes of sediment involved in the dynamics along the south beach of the WEST SIDE and TIP, supports the hypothesis that the west beach is in part supplied by sediment eroded from the east beach. In this case, sediment supplied to the west beach would be expected to diminish northward as the data indicate.

Noted earlier, was the exception to the growth trend of the WEST SIDE beach at E-1-27. It is interesting to note, that although the net change in beach width and volume are negligible (<1 m and <1 m^2), and the range between the minimum and maximum profile was relatively small

TABLE 2.

SUMMARY OF WEST SIDE AND WEST TIP BEACH PROFILE DATA 1974 - 1981*

		RECESSION/ACCESSION			EROSION/DEPOSITION				
STATION	REACH LENGTH (km)	NET CHANGE (m)	GROSS CHANGE (m)	RANGE (m)	NET CHANGE (m^2)	GROSS CHANGE (m^2)	RANGE (m^2)	TIME OF MIN (M-Y)	TIME OF MAX (M-Y)
WEST SIDE									
E-1-25	3.22	6	20	6	10	38	9	6-74	7-81
E-1-26	3.89	5	36	8	5	35	11	11-75	7-81
E-1-26D	1.61	10	28	28	12	39	14	4-75	7-80
E-1-27	1.61	< 1	32	7	< 1	51	10	7-80	8-76
E-1-27A	1.29	18	28	19	28	47	31	6-74	7-81
WEST TIP									
E-1-27B	.16	- 17	54	21	-30	77	34	7-81	10-74
SPOKE 1	N/A	- 25	59	32	-43	85	46	9-80	10-75
SPOKE 2	N/A	- 37	61	37	-65	122	72	9-80	5-75
SPOKE 3	N/A	-110	408	130	-159	577	207	9-80	5-78

* Negative values indicate recession and erosion.
Spoke profiles were not surveyed in 1981.

(7 m and 10 m^2), more material was lost and gained during the survey period (51 m^2), than at any other station.

The WEST TIP beach receded considerably during the same period that the WEST SIDE beach gained. Net recession ranged from 17 m at E-1-27B, to 110 m at Spoke 3, with corresponding losses of 30 m^2 and 159 m^2, respectively. The larger losses measured at the spokes is in part due to the angle that the survey line intersects the beach. In spite of this, however, the data shows a net shift to the east of the WEST TIP beach, and a shortening of the tip of the spit. WEST TIP beach minimums were generally at the time of WEST SIDE beach maximums, and vice-versa.

East Side and East Tip

Changes to the EAST SIDE and EAST TIP beaches were similarly contrasting, but with the former generally eroding, and the latter generally gaining. Profile plots (Appendix 1) and time-series plots of sediment volumes (Appendix 3) show that most of the erosion to the EAST SIDE beach occurred during the initial years of the survey (1974-1976), and that during this period, it generally increased toward the north. Averaged annual rates of erosion (Table 3) varied from marginal near the tip, to 50 m^2 at the north end of the Park (E-1-30). Volume losses were accompanied by corresponding landward shifts in the foreshore of up to 32 m. Large shifts of this magnitude represent more than just a loss to the foreshore, but also, a displacement of the entire beach profile into the marsh. Overall, the east beach lost an average of 16 m^2 of sediment annually that resulted in an annual recession of 3 m. It is on account of this migration of the beach system, that some stations needed to be re-established on a continuous basis, or were discontinued where it was not possible to recover survey monuments.

TABLE 3.

ANNUAL CHANGES IN EAST SIDE AND EAST TIP BEACH PROFILES*

STATION	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81
EAST SIDE EROSION/DEPOSITION (m^2)							
E-1-30	-35.7	-50.3	4.3	- 3.7	.3	- 5.9	1.0
E-1-29.5				13.1	69.7	6.2	14.8
E-1-29.4				22.5	20.3	22.6	30.1
E-1-29.3				- 3.4	3.2	- 5.4	2.7
E-1-29.2				-13.9	-17.0	- 3.2	
E-1-29.1				- 2.8**	- 2.8**	- 2.8**	
E-1-28H	-21.7***	-21.7***	-21.7***	2.3	8.5	2.5	11.3
E-1-28D	-10.3	- 7.8		(discontinued after 1976)			
E-1-28	-13.5	3.7	1.5	- 3.5	- 2.4	- 1.6	.1
E-1-27D	-12.7	.9	- 5.9	- 3.0	1.4	- 4.2	- 1.1
EAST TIP EROSION/DEPOSITION (m^2)							
E-1-27C	6.9	-11.8	9.9	14.2	7.2	- 1.9	1.1
SPOKE 6	.3	- 8.3	25.0	13.9	16.6	-34.9	(no data)
SPOKE 5	- .6	- 5.7	38.4	2.1	23.1	-38.9	(no data)
SPOKE 4	7.8	-10.8	48.9	5.2	31.0	-40.5	(no data)
EAST SIDE RECESSION/ACCESSION (m)							
E-1-30	-19.0	-32.7	5.8	- 5.1	- .8	- .8	2.8
E-1-29.5				- 2.8	43.9	- 3.2	5.9
E-1-29.4				13.6	19.7	14.8	11.5
E-1-29.3				-11.5	.4	- 3.1	1.2
E-1-29.2				- 6.4	- 9.5	- 5.5	0.0
E-1-29.1				- 2.9**	- 2.9**	- 2.9**	
E-1-28H	-12.0***	-12.0***	-12.0***	1.4	7.9	- 5.5	3.4
E-1-28D	- 5.5	- 3.6		(discontinued after 1976)			
E-1-28	- 6.8	2.2	1.6	- 2.0	- 2.4	- 1.0	1.9
E-1-27D	- 7.4	1.0	- 2.8	- 1.8	.5	- 5.0	- 3.1
EAST TIP RECESSION/ACCESSION (m)							
E-1-27C	4.8	- 6.5	7.1	6.6	5.3	0.0	- 1.6
SPOKE 6	.6	- 1.5	14.3	6.5	12.9	-22.4	(no data)
SPOKE 5	- 2.5	- .7	35.8	-11.3	16.6	-19.5	(no data)
SPOKE 4	7.3	- .9	37.1	- 7.1	27.5	-26.7	(no data)

* Differences from preceding observation (annual averages).
Recession is measured at 174.0 m above IGLD.
Negative values indicate erosion and recession.
** Annual average 1977-1980.
*** Annual average 1974-1977.

The relatively large losses incurred during the initial years is likely in response to the extreme lake levels of 1973. In another study of shore recession in the Great Lakes, Hands (in Komar, 1983) found that high recession rates persisted for two years after lake levels had peaked. Although, the EAST SIDE beach is showing signs of continued erosion, rates have reduced significantly. Since 1976, annual rates of erosion are about 10% of the levels incurred during 1974/75, and in some cases, the beach is recovering (northern sector).

Rates of erosion since 1976 also appear to be more evenly distributed from north to south, as the higher rates of erosion noted for the northern reaches during the first two years are no longer apparent. This suggests that the northern reaches may have been influenced by factors other than high lake levels and storms. For example, Bayly (1977) shows that the series of groynes located immediately to the north of the Park boundary at E-1-30, interrupted the supply of sediment from the north which eventually led to the breaching of the Park shore at Bush Pond. Severe erosion also effected the reach of shore protected by the groynes, especially to the south of the system where groynes were no longer tied to the shore. With the groyne field at the outer limits of the littoral transport zone, its effectiveness in trapping littoral drift had diminished significantly. As a result, sediment supply from the north continued uninterrupted toward the Park reaches of shore.

The EAST TIP generally gained in material, particularly from 1976 to 1979, and as with the WEST TIP, response form one station to the next was relatively uniform, suggesting the effect of a predominant process (e.g. currents). The relationship between the west and east sides of the tip on the long-term is inverse with the west side losing and the east side gaining. However, in comparing annual changes (Tables 1 and 3), there is a direct relationship with periods of erosion and accretion occurring simultaneously, for example, both sides of the tip incurred significant losses in 1980. This relationship appears to be fairly localized, as corresponding changes to the southern reaches of the WEST and EAST SIDE beaches are not apparent.

Quantitative changes to the EAST SIDE and EAST TIP beaches are summarized in Table 4. In looking at the stations having a full period of record, the net change from summer of 1974 to the summer of 1981 shows the east beach receded everywhere with losses of 6 - 19 m for the lower 5 km of beach, to 29 m and 49 m in the northerly reaches. Corresponding losses in beach volume ranged from 16 - 27 m^2 and 42 - 92 m^2, respectively. As indicated earlier, however, most of this erosion occurred during 1974-1976. The total amount of material recorded entering and leaving the beach zone at each station (gross change) increased from 35 m^2 near the tip (E-1-27D), to 108 m^2 at the most northerly reach (E-1-30). Together, this data indicates the magnitude of beach dynamics increases progressively toward the north along the EAST SIDE beach, which is in contrast to the WEST SIDE. The range from minimum to maximum beach profile (m^2) also increased from south to north. Because the east beach never fully recovered from the erosion incurred during the early 1970's, the time of maximum profile was the same for all regularly monitored stations (June, 1974). The time of minimum profiles, however, varied considerably from station to station indicating the lack of a dominant process element.

In contrast to the net losses recorded for the entire east shore, the EAST TIP showed increases of 22 - 52 m^2 in profile area, and

TABLE 4.

SUMMARY OF EAST SIDE AND EAST TIP BEACH PROFILE DATA 1974-1981*

		RECESSION/ACCESSION			EROSION/DEPOSITION				
STATION	REACH LENGTH (km)	NET CHANGE (m)	GROSS CHANGE (m)	RANGE (m)	NET CHANGE (m^2)	GROSS CHANGE (m^2)	RANGE (m^2)	TIME OF MIN (M/Y)	MAX (M/Y)
EAST SIDE									
E-1-30	2.22	- 49	73	54	- 92	108	92	9-80	6-74
E-1-29.4**	.60	60	60	60	96	106	96	9-77	7-81
E-1-29.3**		- 13	28	18	- 3	17	10	9-80	9-79
E-1-29.2**					- 36	35	36	9-77	7-81
E-1-29.1**	.60	- 9	9	9	- 9	9	9	9-77	9-80
			(no data 1978 and 1979)						
E-1-28H	2.34	- 29	67	38	- 42	96	69	7-77	6-74
			(no data 1975 and 1976)						
E-1-28D	1.61	- 9	16	11					
			(discontinued after 1976)						
E-1-28	1.61	- 6	35	9	- 16	49	17	11-75	6-74
E-1-27D	1.61	- 19	35	19	- 27	35	27	7-81	6-74
EAST TIP									
E-1-27C	.40	18	52	21	22	84	31	8-76	6-79
SPOKE 6	N/A	14	109	37	15	156	56	8-76	9-79
SPOKE 5	N/A	19	143	53	21	192	64	6-75	6-79
SPOKE 4	N/A	45	194	70	52	222	90	5-75	9-79

* Negative values indicate recession and erosion.
** Surveyed 1977-1981.

increases in beach width of 18 - 45 m. The larger changes observed for the Spoke stations is in part due to the angle at which the survey line intersects the beach. Net growth of the EAST TIP occurred largely as the result of significant accumulation during 1976-1979, a period when the EAST SIDE beach was also recovering from excessive losses in the early 1970's.

5.1.2 Nearshore and Offshore Zones

For this study, the nearshore zone extends from the outer limits of the beach zone at 174.0 m (IGLD), to about a 3 m depth at the 171.0 m (IGLD) contour. The nearshore zone is generally considered an integral part of beach dynamics as it is primarily within this zone that beach sand is stored, transported and supplied in the form of shifting submarine bars. The offshore zone represents the remaining portion of the submerged profile below the 171.0 m (IGLD) contour, to the offshore limit of the sand spit. No changes are assumed to take place beyond the limits of the offshore zone, as the glacial clay bottom is considered to be relatively stable. Offshore surveys are adjusted to close on the clay bed. Closure depths are indicated in the summary tables of the offshore profile data (Tables 8 & 11).

West Side and West Tip

From the record of profile plots shown in Appendix 2, submarine bar development on the WEST SIDE is most pronounced along the northerly reaches particularly at E-1-26. Maximum crest heights reach .7 m and are either in the form of a large single bar, or as a series of bars that extend further offshore. An example of a well formed single bar is observed from 1974 to 1976. Crest height is .7 m and varies from about 75 m to 125 m offshore. By 1977, mean lake level had dropped about 40 cm, and the single bar which predominated up to this time was redistributed into an inner and outer bar. Position of the outer bar ranged between 100 - 150 m offshore, and generally showed a direct response to shifts in mean lake level. For example, a 40 cm drop in lake level between 1974 and 1977 resulted in a 20 - 40 cm lowering of the bar crest. Multi-bar development (up to 4) was also observed with the weak outer bar at distances of up to 210 m offshore (E-1-25 in May 1979, and E-1-26 in Sept. 1978). In any case, submarine bars were all within a 3 m depth.

In contrast, southerly reaches have either no bars present, or weak single bar development that is discontinuous along the shore. Bar crests are generally less then .5 m in height, and relatively stationary at about 150 m offshore. The drop of 40 cm in mean lake level between 1974 and 1977 generally eliminated any former presence of submarine bars.

The nearshore and offshore portions of the profile, shown in Appendix 2, are plotted as sweep zones in Figure 11, to further indicate where changes are occurring along the submerged profile of the Pelee shoreline. The sweep zone represents the envelope of shore profiles measured during the survey period. The trend of diminishing bar development toward the south is evidenced by the narrower sweep zones of the nearshore zone. Sweep zones indicate that (although submarine bar activity is exclusively within the 3 m depth) the active zone of the submerged profile of the WEST SIDE extends beyond the nearshore zone to the base of the Pelee rise. Sample plots within the sweep zone not only

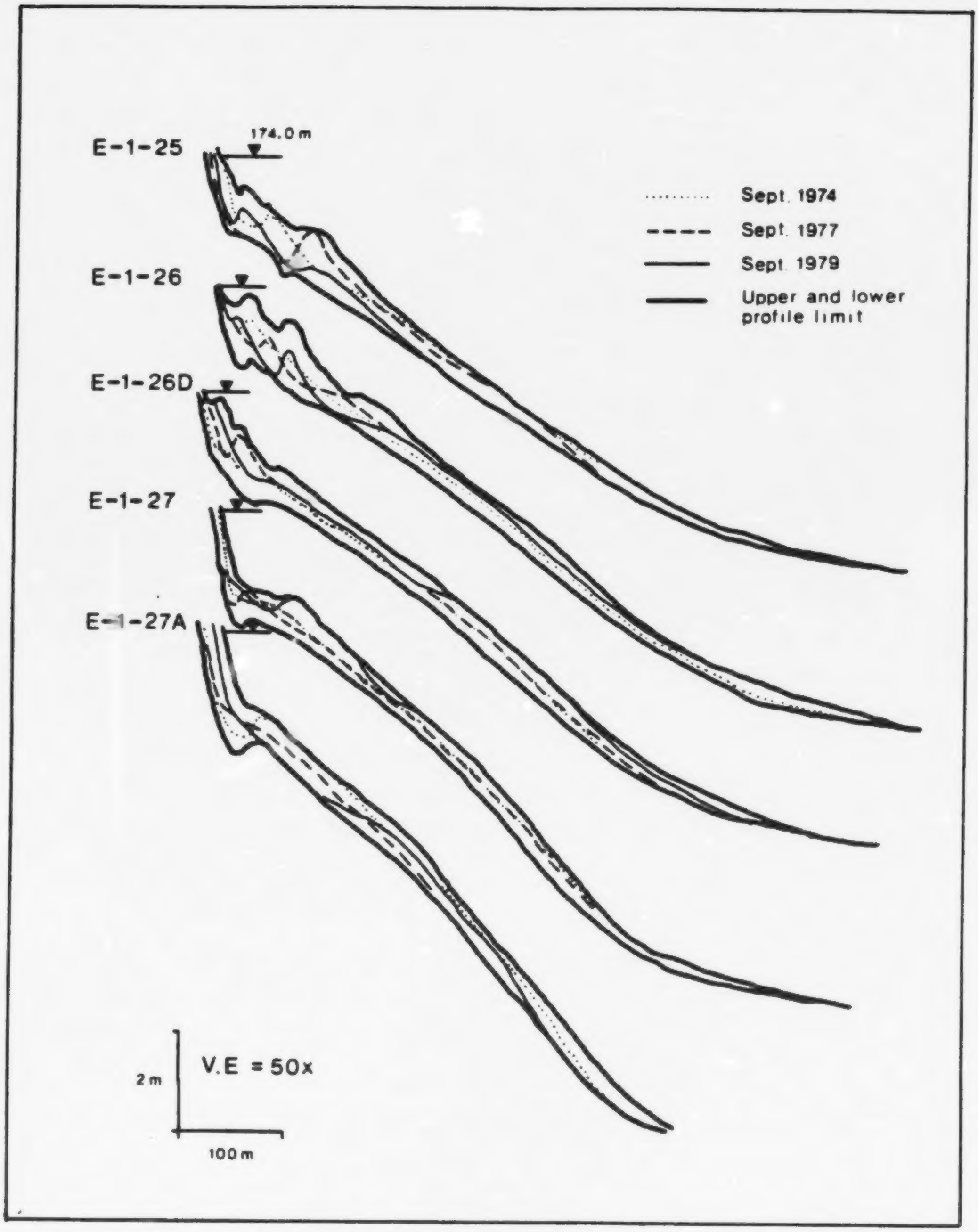

Figure 11. Sweep Zones for the WEST SIDE of Point Pelee 1974-1981

show the onshore-offshore movement of sand bars within the nearshore zone, but also the presence of narrow sand lenses further offshore which account for the breadth of the sweep zones at these greater depths. Although sounding and positioning errors may also contribute to the broad sweep zones of the offshore zone, changes of this magnitude can be expected, as the Point Pelee spit is migrating westward. Evidence of large shifts to the west base of the Pelee rise is also reported by Coakley et al (1972).

As with the southerly reaches of the WEST SIDE, WEST TIP profiles indicate minimal development of submarine bars in the nearshore. Sweep zones (Fig. 12) also show relatively small shore displacements, with the exception of the nearshore zone at Spoke 3 which is effected by shifts in the tip of the spit. Changes in the bathymetry of the offshore zone of the tip further indicate the magnitude of sediment dynamics beyond the littoral zone (3 m depth). For example, a 2 m trough developed at the 8 m depth of Spokes 1 and 2 in 1978. Infilling was evident in subsequent surveys, along with the build-up of a submarine bar on the lake side of the trough 350 m offshore. Such a feature may account for what Coakley et al (1972) interpreted to be recession of the west edge of the Pelee rise between the years of 1964 and 1971.

A pronounced bar-like feature was also observed in the offshore zone of E-1-27B at 4-5 m depth . This feature persisted throughout the entire survey period and remained relatively stationary. In addition, rather than the conventional trough/crest bar configuration, the crest of the feature rises between two troughs. Because of its unique characteristics, its origin is not likely related to a break-point bar, but rather the result of a prevailing process such as the hydraulic gradient currents which circumvent the tip of Point Pelee. Lake

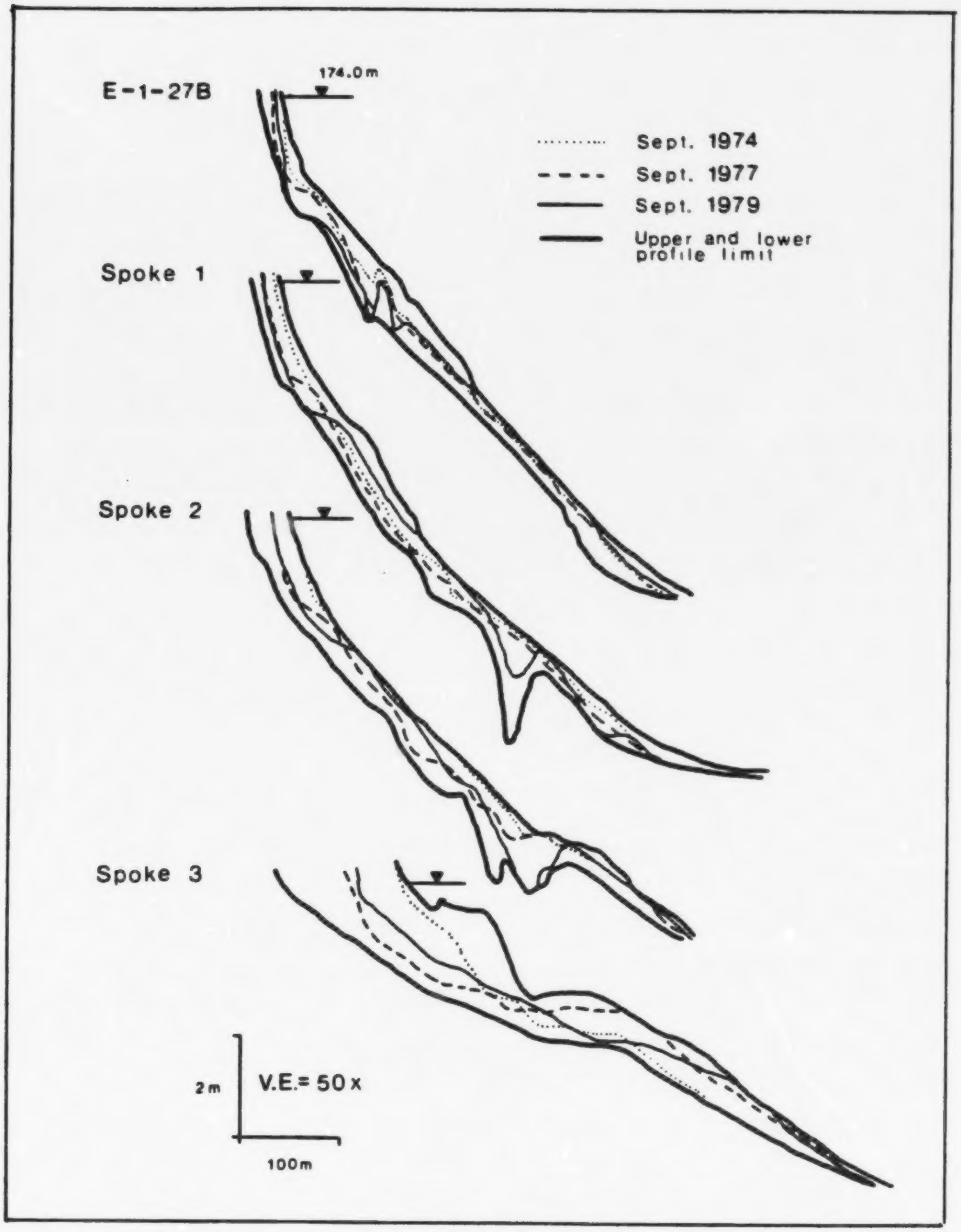

Figure 12. Sweep Zones for the WEST TIP of Point Pelee 1974-1981

currents are also thought to be the cause of the trough that developed at the base of the offshore profile of Spokes 1 and 2.

For an indication of the trends occurring in the nearshore of Point Pelee, volumetric measurements of changes in profile and shifts in the position of the 171 m (IGLD) contour, are reduced to annual averages in Table 5. Losses of nearshore sediments occurred at all survey sites in 1975 and 1979, particularly in the northern reach of the WEST SIDE where annual rates were observed to be 55 m^2 and 52 m^2 respectively. Losses did not exceed 21 m^2 for the more southerly reaches of the WEST SIDE. 1976 through to 1978 were years of marked accumulation. However, maximum annual gain did not exceed 33 m^2. The breadth of the nearshore also shifted in response to the redistribution of sediments noted above, with maximum annual shifts of up to 19 m, again noted for the more northerly stations.

WEST TIP profile changes generally corresponded to the erosion trends of the WEST SIDE indicating a response to a common process element such as lake level. However, no direct relationship to mean lake level changes is evident that would correspond with the periods of erosion or accretion except to note that lake levels were generally declining, or relatively low, during the period of accumulation (Appendix 3). Maximum changes occurred at Spoke 3 (up to 193 m^2) in response to the shifting tip of the sand spit. The large shifts of sediment, however, did not appear to extend much along the west shore (e.g. <.5 km), as annual volumetric changes of tip profiles were similar in magnitude to those of the WEST SIDE.

Table 6 indicates that sediment losses and gains in the offshore are up to 2 times than which occurred in the nearshore from year to

TABLE 5.

ANNUAL CHANGES IN WEST SIDE AND WEST TIP NEARSHORE PROFILES*

STATION	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81
WEST SIDE EROSION/DEPOSITION (m^2)							
E-1-25	- 7.7	20.2	- 7.0	32.9	-52.0	32.6	-23.4
E-1-26	-55.1	19.8	- .6	32.9	-29.1	15.2	-25.6
E-1-26D	-16.4	21.0	24.6	15.3	-21.4	-16.4	- .9
E-1-27	- 2.9	12.6	- 9.4	26.0	-14.1	-20.5	6.1
E-1-27A	-11.4	1.5	23.9	28.7	-20.3	19.6	- 6.4
WEST TIP EROSION/DEPOSITION (m^2)							
E-1-27B	- 4.5	8.4	- 7.3	4.2	-20.6	- 5.7	-14.4
SPOKE 1	-21.0	-15.8	- 4.3	10.6	-10.3	-28.2	(no data)
SPOKE 2	-41.2	31.1	-40.0	14.7	- 5.4	-38.2	(no data)
SPOKE 3	-171.0	179.9	-88.7	129.2	-31.2	-192.7	(no data)
WEST SIDE RECESSION/ACCESSION (m)							
E-1-25	- 7.5	1.0	9.9	18.9	-11.9	6.3	- 5.6
E-1-26	-15.0	10.8	3.6	15.4	- 9.9	- 2.0	-12.0
E-1-26D	-11.6	2.4	17.2	13.5	-11.1	- 2.5	- 3.8
E-1-27	- 5.0	1.0	- 3.2	- .6	11.1	- 6.5	- 1.0
E-1-27A	-13.6	3.5	2.7	13.9	-16.9	.1	6.5
WEST TIP RECESSION/ACCESSION (m)							
E-1-27B	- 4.3	- 4.1	4.5	8.6	- 8.5	- 3.6	1.2
SPOKE 1	- 5.9	- 9.7	8.6	9.6	7.7	-11.0	(no data)
SPOKE 2	-17.9	10.7	- 9.3	9.1	10.3	- .3	(no data)
SPOKE 3	-43.4	114.0	7.7	- 1.4	-83.3	-51.9	(no data)

* Differences from preceding observation (annual averages).
Negative values indicate erosion and recession.
Recession is measured at 171.0 m above IGLD.

year. Although periods of erosion and accumulation generally correspond with those of the nearshore, the large volumes of sediment in the nearshore of Spoke 3, that are in response to shifts of the tip of the spit, are absent in the offshore. Annual changes in the offshore profile, in fact, are generally greater on the WEST SIDE then they are at the WEST TIP. This suggests that shifts in the orientation of the submerged tip of the spit do not effect the WEST TIP below a 3 m depth.

TABLE 6. ANNUAL CHANGES IN WEST SIDE AND WEST TIP OFFSHORE PROFILE*

STATION	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81
WEST SIDE EROSION/DEPOSITION (m^2)							
E-1-25	-20.4	10.8	2.4	50.9	-71.2	56.1	-104.8
E-1-26	60.3	29.0	-33.6	84.7	-24.3	6.5	- 37.3
E-1-26D	-16.6	19.3	26.3	69.7	-25.7	-52.3	46.4
E-1-27	-55.2	87.3	-93.4	-28.7	118.1	- 8.8	- 4.7
E-1-27A	-60.7	47.4	-47.8	23.3	40.4	20.6	- 5.4
WEST TIP EROSION/DEPOSTION (m^2)							
E-1-27B	-41.5	10.3	-26.7	76.7	- 5.5	- 6.6	- 3.0
SPOKE 1	28.0	-53.3	- 8.6	15.7	95.9	-22.9	(no data)
SPOKE 2	-18.7	-51.2	-70.1	-17.8	56.3	5.3	(no data)
SPOKE 3	37.0	69.7	12.8	34.9	-52.9	11.0	(no data)

* Differences from preceding observation (annual averages).
Negative values indicate erosion.

A summary of the profile changes in the nearshore and offshore is provided in Tables 7 and 8, respectively. The quantity of sediments effecting the west shore of Point Pelee to a 3 m depth (nearshore zone) increases toward the north, which is in direct contrast to what was observed for beach sediments (Table 2). Gross volumes of sediment in the nearshore increased from 262 m^2 at the tip (Spoke 1), to 495 m^2

TABLE 7.

SUMMARY OF WEST SIDE AND WEST TIP NEARSHORE PROFILE DATA 1974-1981*

		RECESSION/ACCESSION			EROSION/DEPOSITION				
STATION	REACH LENGTH (km)	NET CHANGE (m)	GROSS CHANGE (m)	RANGE (m)	NET CHANGE (m^2)	GROSS CHANGE (m^2)	RANGE (m^2)	TIME OF MIN (M/Y)	TIME OF MAX (M/Y)
WEST SIDE									
E-1-25	3.22	18	143	28	- 4	365	76	8-75	9-78
E-1-26	3.89	- 5	200	48	- 36	495	106	6-75	6-74
E-1-26D	1.61	12	172	41	14	438	95	8-75	5-78
E-1-27	1.61	- 7	206	35	22	384	65	9-80	5-79
E-1-27A	1.29	- 4	198	37	33	357	87	9-74	5-80
WEST TIP									
E-1-27B	.16	9	149	28	- 15	261	53	7-81	10-74
SPOKE 1	N/A	< 1	91	38	- 67	262	84	7-80	5-75
SPOKE 2	N/A	5	116	37	- 87	307	89	7-80	9-74
SPOKE 3	N/A	-93	389	150	-223	998	302	9-80	6-79

* Negative values indicate recession and erosion.
Recession is measured at 171.0 m above IGLD.
Spoke profiles were not surveyed in 1981.

about 7 km north of the tip (E-1-26). The range from the most eroded state to the profile of maximum accumulation also increased toward the north from 53 m^2 at the tip, to 103 m^2 at E-1-26. The more active nearshore zone of the northern reach showed a net loss of sediment (36 m^2) from 1974 to 1981, while net gains of up to 33 m^2 were observed toward the tip. With deposition in the south and erosion in the north, it appears that the sediment supplied to the nearshore from the south is a factor in the nearshore budget of Point Pelee.

The net shift of the WEST TIP beach toward the east was also noted for the nearshore with net losses of up to 223 m^2 and recession of up to 93 m at Spoke 3 from 1974-81. Consequently, early surveys of 1974-75 represent maximum profiles, in contrast to the nearshore of the WEST SIDE which was at its minimum. With the exception of Spoke 3, tip profiles indicate that the west tip is no more dynamic than the nearshore further north, in terms of changes in profile.

Generally, the offshore shows a net gain in sediment between 1974 and 1981 (Table 8). As with the nearshore, the quantities of sediment observed over the period of record are noticeably less at the tip than what was recorded at stations further north. Total volumes range from about 260 m^2 at Spoke 3 to over 1,100 m^2 at E-1-27B. This indicates that shifts in the tip of the spit do not effect the west side of the tip below a 3 m depth. Sediment losses and gains may be minimized due to the flushing action of the prevailing southeasterly currents which reach their maximum velocities at the tip. The time of least sediment in the offshore of the WEST SIDE corresponded to that of the nearshore and beach zones (1974 and 1975), and at a time when the offshore of the tip was at its maximum.

TABLE 8.

SUMMARY OF WEST SIDE AND WEST TIP OFFSHORE PROFILE DATA 1974-1981*

EROSION/DEPOSITION

STATION	REACH LENGTH (km)	CLOSURE DEPTH (m)	CLOSURE DISTANCE (m)	NET CHANGE (m^2)	GROSS CHANGE (m^2)	RANGE (m^2)	TIME OF	
							MIN (M/Y)	MAX (M/Y)
WEST SIDE								
E-1-25	3.22	165.3	800	-34	705	126	7/81	5/78
E-1-26	3.89	164.9	800	10	1042	173	8/75	10/74
E-1-26D	1.61	164.5	800	58	767	218	8/75	5/78
E-1-27	1.61	163.8	750	76	960	156	11/75	9/79
E-1-27A	1.29	163.8	500	12	898	181	8/75	6/74
WEST TIP								
E-1-27B	.16	163.6	500	130	1121	224	5/74	6/74
SPOKE 1	N/A	163.8	800	21	732	228	6/78	5/75
SPOKE 2	N/A	165.1	500	- 52	390	134	5/78	5/75
SPOKE 3	N/A	167.8	700	124	263	171	7/74	9/78

* Negative values indicate erosion.
Spoke profiles were not surveyed in 1981.

The relative significance of the volumes of sediment effecting profile changes in the beach and nearshore/offshore zones of the west side of Point Pelee becomes particularly apparent in comparing the summary tables (Tables 2, 7 and 8). The quantity of sediment lost and gained in the nearshore averages 10 times that of the beach. If the volumes below the 3 m depth are also considered, the combined offshore quantities are 30 times that of the beach. The beach, therefore, represents only a minor fraction (3%) of the sediment budget of the west shore of Point Pelee.

East Side and East Tip

Two of the original 5 stations established to monitor profile changes along the EAST SIDE of Point Pelee have incomplete records as a result of excessive beach erosion. Together, these represent about 4 km of the central part of the east beach. One station (E-1-28H) was re-established in 1977, however, the other (E-1-28D) was discontinued after 1976, as survey monuments were never recovered. An additional 5 survey stations were added in 1977 (E-1-29.1 to 29.5) to continue the monitoring of shore changes along this highly erodible reach of shore.

In contrast to the west shore of Point Pelee, which is prograding, the extent of sand deposits offshore the EAST SIDE is considerably less. Based on profile interpretation, and a review of the literature, sand deposits taper out to a solid glacial clay material at about 275 to 600 m offshore, and is at depths ranging between 3 to 6 m.

A complete record of the surveys of the nearshore and offshore is provided for each station in Appendix 2. During the survey period, the east side of Point Pelee was characterized by a large submarine bar that extends the full length of the Point at 100 - 225 m offshore. Although a primary bar ranging in height from 2 - 2.5 m is always evident, a small inner bar, and weak outer bars at distances of up to 300 m offshore and at depths of 4-5 m, were also observed. Changes in bar morphology were gradual. The shape and number of bars observed in the spring, generally persisted through to the fall. Major changes in bar morphology occurred between the fall and spring surveys, most likely in response to easterly spring storms.

The dimensions of the sweep zones (Fig. 13) are much larger than those of the west shore, and submarine bars extend well below 171.0 m (IGLD). Water depths may vary by as much as 2.5 m at distances of 300 m offshore as a result of the redistribution of sand in the nearshore bar system. Maximum changes in the nearshore of the west side, in comparison, did not exceed 1.5 m, and were less than 150 m offshore. Profiles from Sept. 1974, 1977 and 1979 are included with the sweep zone plots to show the variability of the nearshore and offshore morphology. Although the most active part of the profile in terms of changes in shore morphology is generally above the 4 m depth, significant changes also occur to the 6 m depth along the more northerly reaches of the EAST SIDE. For this reason, it would be more realistic to consider the nearshore and offshore zones of the east side of Point Pelee as a large "nearshore zone", as the profile below the 171.0 m contour is very much part of the submarine bar system.

Profile plots and sweep zones also indicate the significance of the sediments which accumulate on the subaqueous tip of Point Pelee. Sweep zones vary by as much as 4 - 5 m, and the majority of sediments are deposited within 1800 m offshore (Fig. 14). Sediments in this area

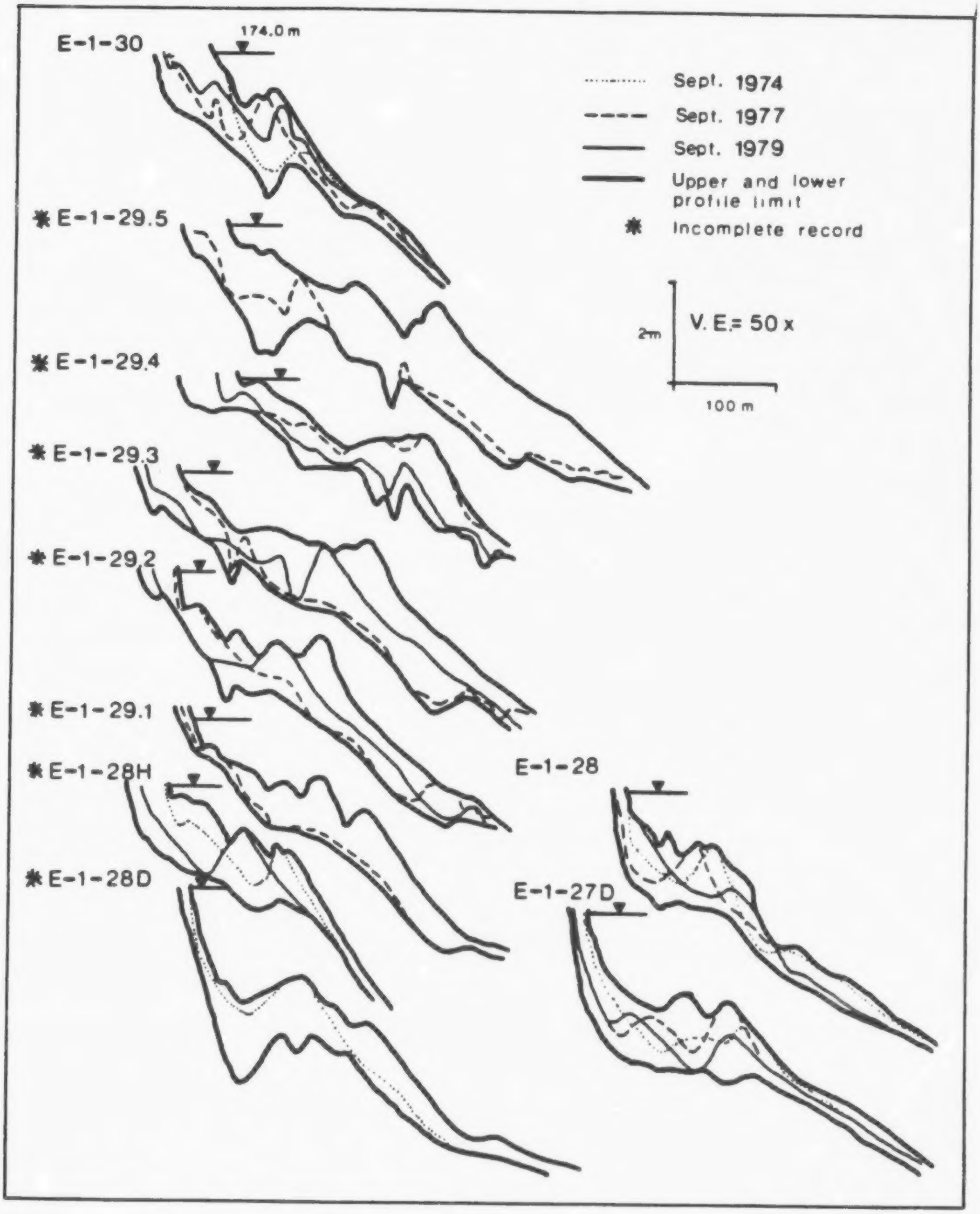

Figure 13. Sweep Zones for the EAST SIDE of Point Pelee 1974-1981

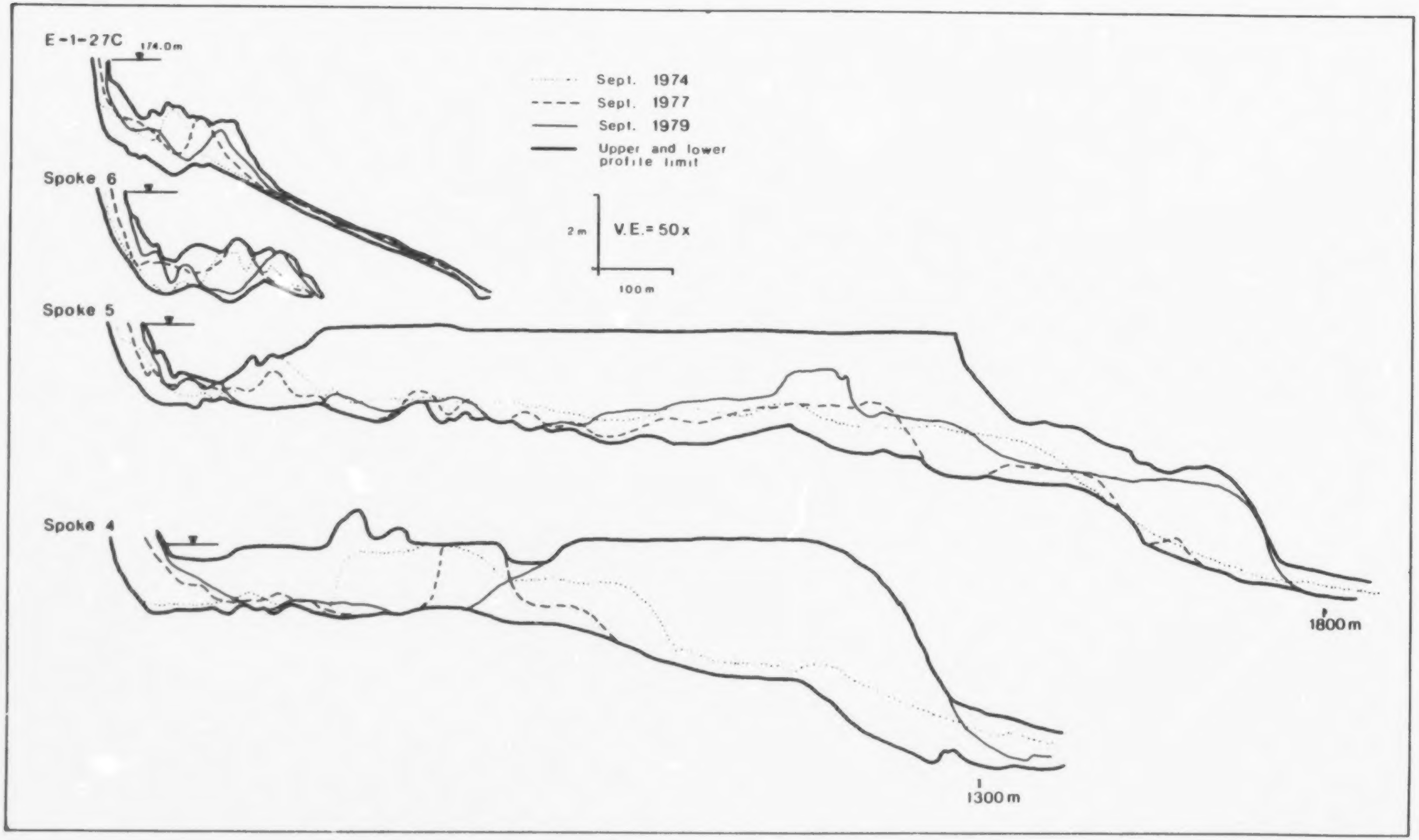

Figure 14. Sweep Zones for the EAST TIP of Point Pelee 1974-1981

are continuously shifting in response to strong currents that are produced by the hydraulic gradient between lake levels of the west and east sides of Point Pelee. Water level records indicate differences can exceed 1 m. Sand deposits do extend beyond 1800 m, however, accumulations are minor relative to those nearer the tip.

Annual changes in sediment volume and recession for the nearshore zone of the east side of Point Pelee are shown in Table 9. Periods of erosion and deposition in the nearshore generally correspond with those of the west side of Point Pelee. 1974-75 and 1979-80 were periods of erosion with losses reaching maximums of 69 - 105 m^2. Between 1975 and 1979 was a period of fluctuating accumulation but in most cases not enough to overcome the losses incurred in 1975 (Appendix 3). Maximum net gain did not exceed 31 m^2, except near the breach site where the beach was being artificially nourished with trucked-in sand. In spite of prevailing erosion conditions during certain years, not all stations show corresponding recession of the nearshore zone. For example, at E-1-28D, a lakeward advance of 22 m occurred at the same time that 69 m^2 was eroded from the nearshore profile. This points to the fact that linear measurements of recession cannot be used as the only indicators of erosion. While material was eroded from the nearshore, there was a lakeward advance of the submarine bar.

Periods of erosion and deposition occurring simultaneously on the west and east sides of Point Pelee suggest that a common process element, such as mean lake level, might be an important factor in the long-term fluctuations of sediment in the nearshore zone. Although levels during the survey period did not vary significantly, mean lake level during the period of net accumulation was low (174.11 m IGLD) relative to the levels during the periods of erosion (174.18 m to 174.51

TABLE 9.

ANNUAL CHANGES IN EAST SIDE AND EAST TIP NEARSHORE PROFILES*

STATION	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81
EAST SIDE EROSION/DEPOSITION (m^2)							
E-1-30	- 37.0	2.0	- 6.5	3.7	18.9	- 39.8	15.9
E-1-29.5				159.5	69.1	-105.3	- 21.0
E-1-29.4				- 32.0	- 54.9	- 19.5	5.4
E-1-29.3				203.3	- 93.8	31.4	- 19.5
E-1-29.2				- 42.9	81.2	- 57.3	33.2
E-1-29.1				- 31.5**	- 31.5**	- 31.5**	
E-1-28H	- 42.0***	- 42.0***	- 42.5***	37.4	40.4	- 37.1	2.8
E-1-28D	- 68.7	- 5.1		[discontinued after 1976]			
E-1-28	- 44.1	24.9	- 4.0	6.1	4.4	- 20.4	10.9
E-1-27D	- 21.0	20.4	- 22.6	28.5	- 19.5	- 24.3	12.3
EAST TIP EROSION/DEPOSITION (m^2)							
E-1-27C	- 16.0	16.9	20.0	21.5	- 6.0	- 37.0	- .1
SPOKE 6	65.3	- 19.6	26.8	25.0	- 3.9	- 72.9	(no data)
SPOKE 5	753.1	-1153.4	3.0	120.1	389.6	1867.6	(no data)
SPOKE 4	-149.7	645.7	-555.8	512.2	141.7	-767.6	(no data)
EAST SIDE RECESSION/ACCESSION (m)							
E-1-30	7.1	-13.2	- 5.4	4.3	3.9	- 6.0	2.6
E-1-29.5				81.0	30.9	8.4	- 3.4
E-1-29.4				- 14.6	- 24.4	- 10.2	4.6
E-1-29.3				85.0	- 19.6	4.5	- 8.5
E-1-29.2				18.9	27.0	- 13.0	2.4
E-1-29.1				- 17.5**	- 17.5**	- 17.5**	
E-1-28H	- .7***	- .7***	- .7***	- 1.6	- 10.5	.8	- .3
E-1-28D	21.6	- 16.7		[discontinued after 1976]			
E-1-28	3.3	10.0	- 7.2	- 1.8	8.8	- 2.9	11.2
E-1-27D	- 52.5	43.0	- 7.0	16.1	- 10.0	- 2.1	- 5.7
EAST TIP RECESSION/ACCESSION (m)							
E-1-27C	14.1	12.6	- 3.1	17.0	4.0	- 13.0	- .2
SPOKE 6		[171.0 m above IGLD is the closure depth - no change]					
SPOKE 5	- 80.8	-468.7	- 27.9	62.7	518.0	60.7	[no data]
SPOKE 4	-128.0	216.0	-189.2	159.4	27.9	-179.3	[no data]

* Differences from preceding observation (annual averages).
Negative values indicate erosion or recession.
Recession is measured at 171.0 m above IGLD.

** Annual average 1977-1980.

*** Annual average 1974-1977.

m (IGLD)).

Annual changes in sediment volumes also show the relationship between periods of erosion and deposition along the west and east sides of Point Pelee (Tables 5 and 9), with accumulations of sediment at the tip (Table 9). Deposition of sediments along Spoke 5 was greatest when the east and west nearshore zones were eroding. For example, 753 m2 of sediment were deposited along Spoke 5 in 1974-75, and nearly 1900 m^2 in 1979-80. In fact, Spoke 5 was the only profile which showed major accumulation of sediment for these periods. The tip lost sediment, or had minor accumulations, when the nearshore of the east and west sides were more stable. This suggests that the large deposits of sediment which accumulate on the subaqueous spit are, in large part, derived from the eroding shores of Point Pelee. Furthermore, the submerged spit to a distance of 1.8 km is probably the most important area with respect to offshore supplies of sediment that feed the shores and shoals of Point Pelee. Sediments beyond this distance may be a potential source (as suggested in other studies), however, the volumes of sediment relative to what is available within 1.8 km of the tip are insignificant.

Annual changes of sediment volume in the offshore Table 10, show no trends of erosion and deposition but quantities are comparable to the nearshore zone. This is primarily due to the fact that the east shore is subject to intense storm activity that effects sediments in the form of shifting submarine bars to a depth of at least 6 m . Maximum volumes were recorded at tip profiles, but did not exceed 500 m^2.

Tables 11 and 12 summarize the profile data for the nearshore and offshore zones of the east side of Point Pelee. Both the nearshore and offshore of the EAST SIDE show a net loss of sediment from 1974 to 1981,

TABLE 10.

ANNUAL CHANGES IN EAST SIDE AND EAST TIP OFFSHORE PROFILES*

STATION	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81
EAST SIDE EROSION/DEPOSITION (m^2)							
E-1-30	-28.2	- 2.3	- 8.9	24.0	8.8	-40.1	-18.8
E-1-29.5				156.5	70.5	-14.4	6.6
E-1-29.4				- 22.4	- 40.6	-13.4	18.6
E-1-29.3				181.3	1.6	-11.4	-12.0
E-1-29.2				4.8	55.1	-16.9	- 1.1
E-1-29.1				- 22.5**	-22.5**	-22.5**	
E-1-28.H	- 1.5**	- 1.5**	- 1.5**	- 2.7	- 2.1	- .1	- .2
E-1-28D	-24.0	-50.4		[discontinued after 1976]			
E-1-28	-21.5	-34.2	- 1.0	40.8	-26.4	3.7	- 4.3
E-1-27D	17.8	15.8	- 7.4	28.3	-34.2	19.6	- 6.5
EAST TIP EROSION/DEPOSITION (m^2)							
E-1-27C	18.7	-33.9	45.3	-14.0	6.7	-19.2	[no data]
SPOKE 6		[no offshore data as closure depth is 171.0 m IGLD]					
SPOKE 5	125.1	-490.4	419.1	165.0	-103.1	78.5	[no data]
SPOKE 4	-96.1	50.9	-220.1	244.4	71.8	-167.8	[no data]

* Differences from preceding survey (annual averages).
Negative values indicate erosion.
** Annual average 1977-1980.
*** Annual average 1974-1977.

TABLE 11.

SUMMARY OF EAST SIDE AND EAST TIP NEARSHORE PROFILE DATA 1974-1981*

		RECESSION/ACCESSION			EROSION/DEPOSITION				
STATION	REACH LENGTH (km)	NET CHANGE (m)	GROSS CHANGE (m)	RANGE (m)	NET CHANGE (m^2)	GROSS CHANGE (m^2)	RANGE (m^2)	TIME OF MIN (M/Y)	TIME OF MAX (M/Y)
EAST SIDE									
E-1-30	2.22	- 11	85	30	- 51	309	85	5-80	6-74
E-1-29.5		-100	255	112	102	688	229	9-77	5-79
E-1-29.4	.60	- 45	121	60	-101	356	142	9-78	5-80
E-1-29.3		61	186	84	121	441	203	9-77	9-78
E-1-29.2		35	109	61	14	325	117	6-78	5-79
E-1-29.1	.60	- 53	[53	53]	- 94	[94	94	9-80	9-77]
			[no data 1978 and 1979]						
E-1-28H	2.34	- 14	[22	14]	-107	[268	150	7-77	6-74]
			[no data 1975 and 1976]						
E-1-28D	1.61	[2	107	51	- 90	155	108	8-75	6-74]
			[discontinued after 1976]						
E-1-28	1.61	12	111	26	- 34	331	79	8-75	6-74
E-1-27D	1.61	- 12	198	67	- 6	400	74	7-77	9-78
EAST TIP									
E-1-27C	.40	42	164	70	5	321	81	6-75	9-78
SPOKE 6	N/A	[N/A	N/A	N/A]	40	277	119	6-79	7-74
		[closure depth of 171.0 m IGLD is fixed at 350 m offshore]							
SPOKE 5	N/A	65	1335	698	2251	5129	2597	9-77	7-80
SPOKE 4	N/A	-209	1886	423	-154	6449	1497	9-80	9-79

* Negative values indicate recession and erosion.
E-1-29.1 to E-1-29.5 were surveyed from 1977-1981 unless otherwise noted.

TABLE 12.

SUMMARY OF EAST SIDE AND EAST TIP OFFSHORE PROFILE DATA 1974-1981*

STATION	REACH LENGTH (km)	CLOSURE DEPTH (m)	CLOSURE DISTANCE (m)	EROSION/DEPOSITION NET CHANGE (m^2)	GROSS CHANGE (m^2)	RANGE (m^2)	TIME OF MIN (M/Y)	MAX (M/Y)
EAST SIDE								
E-1-30	2.22	168.9	325	- 7	367	69	7/81	8/75
E-1-29.5		169.5	450	219	525	227	9/77	5/79
E-1-29.4	.6	168.9	475	58	188	105	5/80	9/77
E-1-29.3		168.5	450	160	234	190	9/77	5/79
E-1-29.2		168.2	350	32	150	69	6/78	5/79
E-1-29.1	.6	169.2	350	- 67	[67	67	9/80	9/77]
				[no data in 1978 and 1979]				
E-1-28H	2.34	169.1	275	- 13	[41	15	6/78	6/74]
				[no data in 1975 and 1976]				
E-1-28D	1.61	168.8	325	[- 25	250	130	8/75	6/75]
				[discontinued after 1976]				
E-1-28	1.61	168.7	400	- 41	168	64	9/77	6/74
E-1-27D	1.61	167.9	500	37	308	80	9/74	9/78
EAST TIP								
E-1-27C	.4	167[illegible]	600	58	532	133	6/74	5/80
SPOKE 6	N/A	17[illegible]	350	[no soundings below 171.0 m IGLD]				
SPOKE 5	N/A	168.5	1600	219	1894	640	8/76	9/78
SPOKE 4	N/A	168.5	1300	-174	1810	640	9/77	9/79

* Negative values indicate erosion.
E-1-29.1 to E-1-29.5 were surveyed from 1977 - 1981 unless otherwise noted.

except for the breach site at Bush Pond where there was some accretion. Recovery of the shore at this site is in part due to artificial nourishment and the removal of part of a former groyne system which was obstructing littoral drift. Losses of up to 107 m^2 were greatest along the central reach of the east side. Net erosion resulted in a recession of the nearshore zone along central and northern reaches of 11 - 14 m. Erosion decreased southward toward the tip, at which point the erosion trend reversed with accumulations of up to 2250 m^2. As a further indication of the storage capacity at the tip, gross volumes exceeded 7,000 m^2 and 8,200 m^2 at Spokes 4 & 5, (75 % of which is above the 3 m depth), compared to the next highest volume of 700 m^2 recorded for the nearshore and offshore of E-1-27D on the east side.

In comparing the gross volumes of sediment of the east beach with that of the nearshore and offshore zones, the sediments of the beach represent 12% of the combined offshore volumes. Volumes of the west beach, in comparison, were only 3% of the combined offshore sediments due to an offshore zone that extends to about twice the depth of that on the east shore.

5.1.3 Summary

Annual trends in shore response from 1974 to 1981 indicate that the west beach of Point Pelee is continuing to migrate westward at an average rate of about 1 m/yr, and that the east beach is showing signs of recovery but still had an average loss of 4 m/yr. West beach profiles accumulated at an average rate of about 1.5 m^2 annually, and the net change from 1974 - 1981 suggests sediment is supplied from sources to the north and south. East beach profiles show an average net erosion of 16 m^2 largely as a result of the heavy losses incurred during the initial years of survey following the record high water levels of 1973. Losses during 1974 and 1975 averaged 17 m^2 annually. Although the beach has not fully recovered from the earlier losses, it has been gaining an average of 2.7 m^2 annually since 1976. The excessive rates of erosion at the north east sector of the Park have also ameliorated since 1976, possibly as a result of the reduced effectiveness and removal of shore structures to the north. Based on an annual net loss of 3 m/yr to the width of the Point, the east beach will merge with the west beach at the north boundary of the Park in about 1500 years.

The amount of sediment eroding and accumulating over the seven year survey period indicates that the beach portion of the sand body is minor compared to the amount of sediment active in the nearshore and offshore zones. Quantities of sediment for the west and east beaches are 3% and 12% of the respective offshore budgets.

Profile data indicate changes in offshore morphology along the west shore extend to the base of the Pelee rise at depths of up to 9 - 10 m. Near the tip of Point Pelee, changes in offshore bathymetry occur at the base of the offshore slope as a result of strong currents. In addition, sediment accumulates along the offshore slope as extensions of the submarine bars, and as narrow lenses of sand which migrate down the slope. Submarine bar development along the east shore is continuous along the entire east side of the Point, and occurs at greater depths than on the west side. Offshore sediments, however, do not extend much beyond the 5-6 m depth before a solid glacial clay bottom is encountered, as this shore has been eroding in the long-term.

Annual changes in the nearshore of both the west and east sides of

Point Pelee show that 1974-75 and 1978-80 were periods of erosion, while intervening years was a period of fluctuating accumulation. In comparing the changes in offshore sediments of the west and east sides of Point Pelee with periods of accumulation at the tip of the spit, most material accumulated at the tip when the shore of Point Pelee was eroding. Further, the bulk of this material was deposited within 1800 m of the tip at depths of less than 3 m. This suggests that the submerged tip of Point Pelee to a distance of 1800 m is the more important offshore reserve of sand relative to the volumes of sediment that accumulate further offshore.

5.2 Short-term Adjustments - The Impact of Storms

The impact of storms at Point Pelee is particularly significant, as it is under these conditions that the transfer of sediments would be effected the most. Observations of sediment transfer between the beach and offshore, and transport along the shore are generally lacking and little understood at Point Pelee. With the available data, however, some hypotheses have been developed to account for the Point's westward migration, and sediment transport processes in general.

Water level records for the west and east sides of Point Pelee provide a good indication of the occurrence and severity of storms. Simultaneous records for the west and east water level gauges at Point Pelee cover the periods of 1964 - 1968 and 1973 - 1976, inclusive.

A histogram of the differences in lake level between the west and east sides of Point Pelee is shown in Fig. 15. During the 7 year record, lake levels were higher on the west side of Point Pelee 56% of the time, and higher on the east side 32% of the time. Although differences for the most part were 10 cm or less, they have reached highs of 63 cm during a westerly storm, or as much as 103 cm under an easterly set-up. With the prevailing hydraulic gradient from west to east, the predominant surface current along the west shore is most likely toward the south, with a sub-surface return flow. Current monitoring at a 4 m depth indicates predominant flow was northerly for a brief period of record in the summer and fall of 1974 (Coakley, 1977).

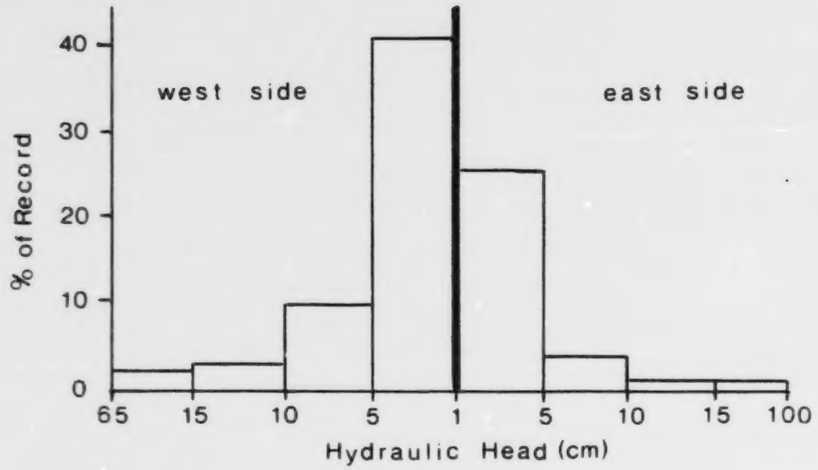

Figure 15. Differences in lake level between the west and east sides of Point Pelee for the periods 1964-68 and 1973-76.

In order to assess the impact of storm conditions in terms of sediment transfer and transport, surveys are required before and after the event. Although it was not possible to have a crew on site waiting for a storm, surveys were carried out frequently enough during 1974 and 1975 to permit the comparison of before and after conditions.

Westerly Storms

In terms of the difference in lake level between the west and east sides of Point Pelee, two of the largest westerly storms to effect Point Pelee during the period of record, occurred during the fall months of 1974 and 1975. During the last week of September, 1974, the west side of Point Pelee was subjected to strong westerly winds which produced a difference in lake level between the west and east sides of Point Pelee of up to 51 cm. Record set-up conditions occurred during the fall of 1975, when a difference of 63 cm was recorded between lake levels of west and east Pelee gauges. A differential of 50 - 60 cm occurs rarely along the west shore of Point Pelee because of the limited fetch distances involved (9 of 45,000 hourly readings exceeded 50 cm).

Beach and offshore surveys were conducted along the west and east sides of Point Pelee (with the exception of profiles covering the submerged tip) 6-10 days in advance of the fall storm of 1974, and the day after the storm subsided. A summary of the impact to west and east shores is provided in Table 13, and as profile plots (Fig. 16-19).

During the storm of 1974, northern and central west beach profiles lost 5 - 8 m^2 (with the exception of E-1-26 which showed minimal response) with recession of up to 7 m, while stations nearer the tip (E-1-27 and 27A) gained 2 - 3 m^2 of beach sediments and accreted 2 - 3 m (Fig. 16). Beach profiles indicate none of this material was transferred inland. Eroded beach sediments appear to have been transported by southerly littoral currents to the beach at the tip (as evidenced by accumulations at E-1-27 and 27A), and to the nearshore and offshore zones where accumulations of up to 49 m^2 and 96 m^2 were recorded (Fig. 17). Sediments that were eroded from the west shore and transported southward, would have likely accumulated on the submerged tip of the spit to a distance of 1800 m, based on profile information collected at the EAST TIP during the monitoring program (see Section 5.1).

Shore response on the east side of Point Pelee to an intense west storm is negligible. Profile data indicate changes in the volumes of

TABLE 13

CHANGES IN BEACH, NEARSHORE AND OFFSHORE POFILES AS A RESULT OF A WESTERLY STORM ON SEPT. 29-30, 1974.*

WEST PELEE				EAST PELEE			
Erosion/Deposition (m^2)							
STATION	Beach	Nearshore	Offshore	STATION	Beach	Nearshore	Offshore
West Side				East Side			
E-1-25	-5	22	<1	E-1-30		(no data)	
E-1-26	<1	42	96	E-1-28H	<1	-1	-4
E-1-26D	-5	11	19	E-1-28D	<1	1	4
E-1-27	-8	-11	12	E-1-28	2	10	-4
E-1-27A	2	49	-71	E-1-27D	<1	<1	3
West Tip				East Tip			
E-1-27B	3	6	49	E-1-27C	1	4	25
				SPOKE 6	-8	-18	N/A
Recession/Accession (m)							
West Side				East Side			
E-1-25	-3	10	N/A	E-1-30		(no data)	
E-1-26	1	18	N/A	E-1-28H	<1	<1	N/A
E-1-26D	-4	- 5	N/A	E-1-28D	<1	1	N/A
E-1-27	-7	3	N/A	E-1-28	1	<1	N/A
E-1-27A	2	21	N/A	E-1-27D	<1	-4	N/A
West Tip				East Tip			
E-1-27B	2	8	N/A	E-1-27C	3	6	N/A
				SPOKE 6	-7	N/A	N/A

* Negative values indicate erosion or recession.

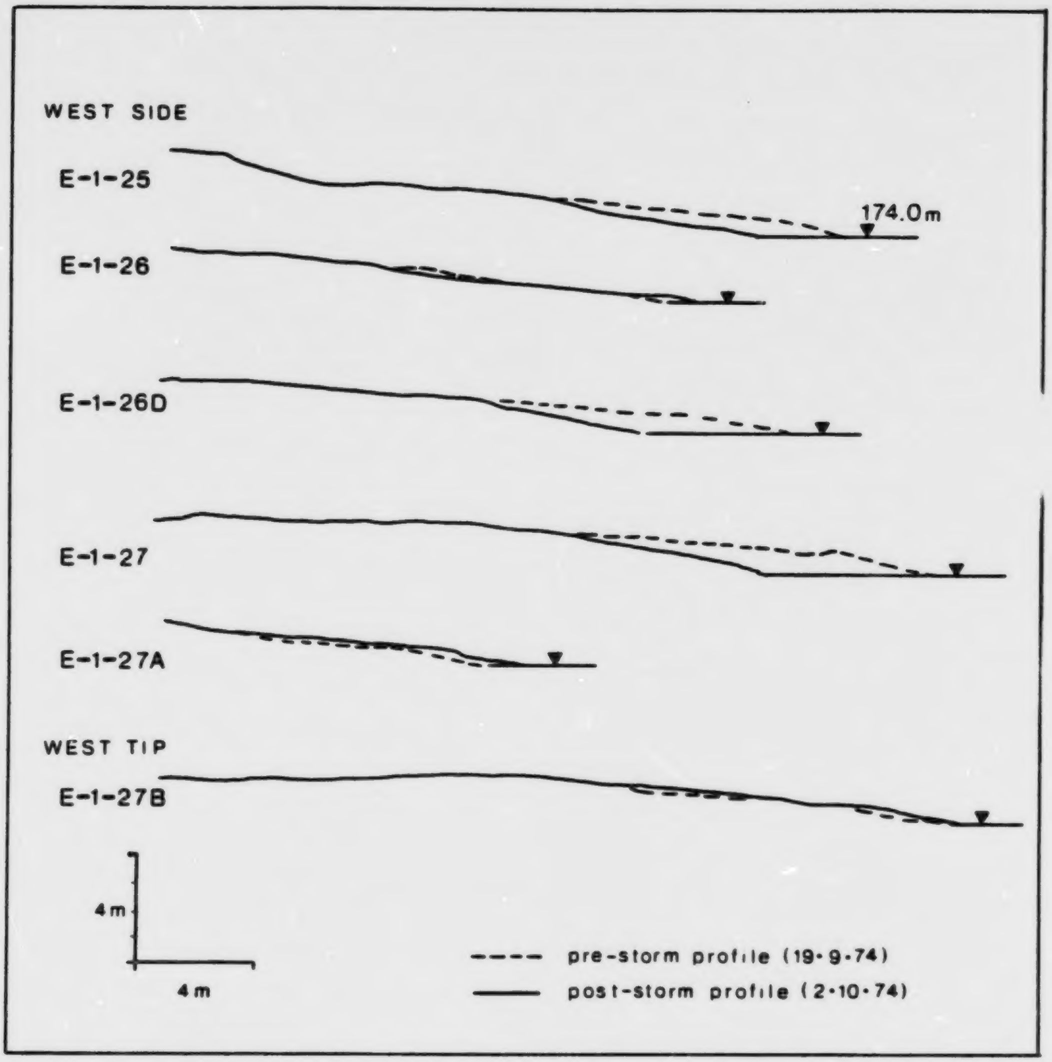

Figure 16. Changes in Beach Profiles of the West Shore of Point Pelee as a Result of a Westerly Storm on Sept. 29-30, 1974

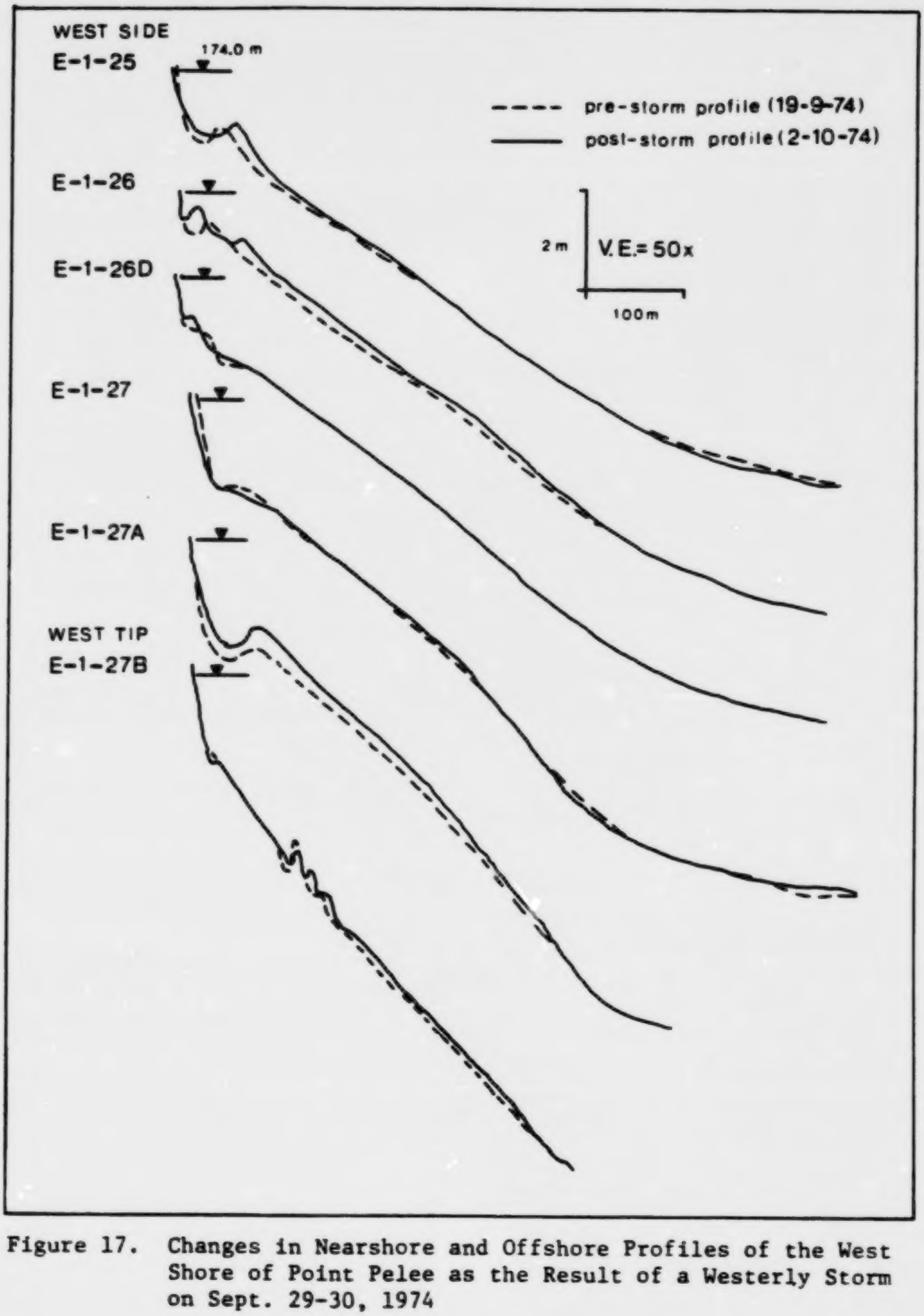

Figure 17. Changes in Nearshore and Offshore Profiles of the West Shore of Point Pelee as the Result of a Westerly Storm on Sept. 29-30, 1974

beach sediment were a fraction of a m^2, except at the tip where the beach profile lost 8 m^2 and receded 7 m. Changes in the offshore were also marginal, generally less than 10 m^2. Figures 18 & 19 show the minor changes which took place in the beach and nearshore/offshore zones. The lack of response on the east side suggests that sediment transfer during a west storm is not a major factor in the sediment budget of the east side of Point Pelee.

Easterly Storms

The east beach of Point Pelee is particularly vulnerable to easterly storm winds because of the fetch distances involved and the low relief of the east beach rim. Water level set-ups are reported to have reached 60 cm (Coakley et al, 1973), and the record from the Point Pelee water level gauges indicates that levels on the east side may be as much as 1 m higher than levels on the west side (e.g. Feb. 1967). Coakley et al (1973) report a loss of 5.5 m^3 of sediment per linear m of beach as the result of an easterly storm at Point Pelee in Nov. 1972. All of this sediment was reported to have been displaced inland. The storm also effected the offshore with erosion increasing shoreward of the 6 m depth. On the basis of other studies, it was hypothesized that the sediments which eroded from the east side nearshore were most likely transported to the west side of Point Pelee. The transfer of sediments under these conditions is thought to be the primary process responsible for the westward migration of the Point. However, this model of sediment transport has never been verified by field data.

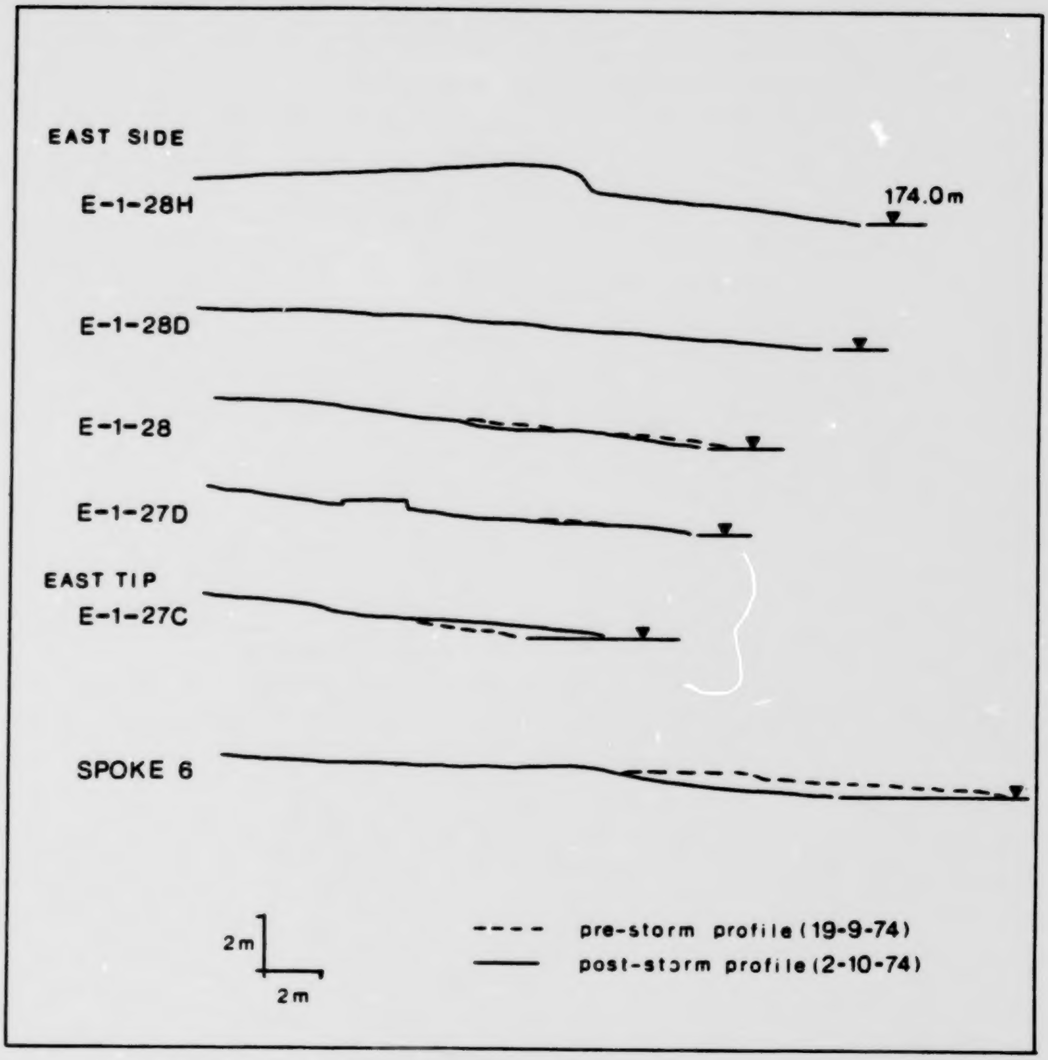

Figure 18. Changes in Beach Profiles of the East Shore of Point Pelee as a Result of a Westerly Storm on Sept. 29-30, 1974

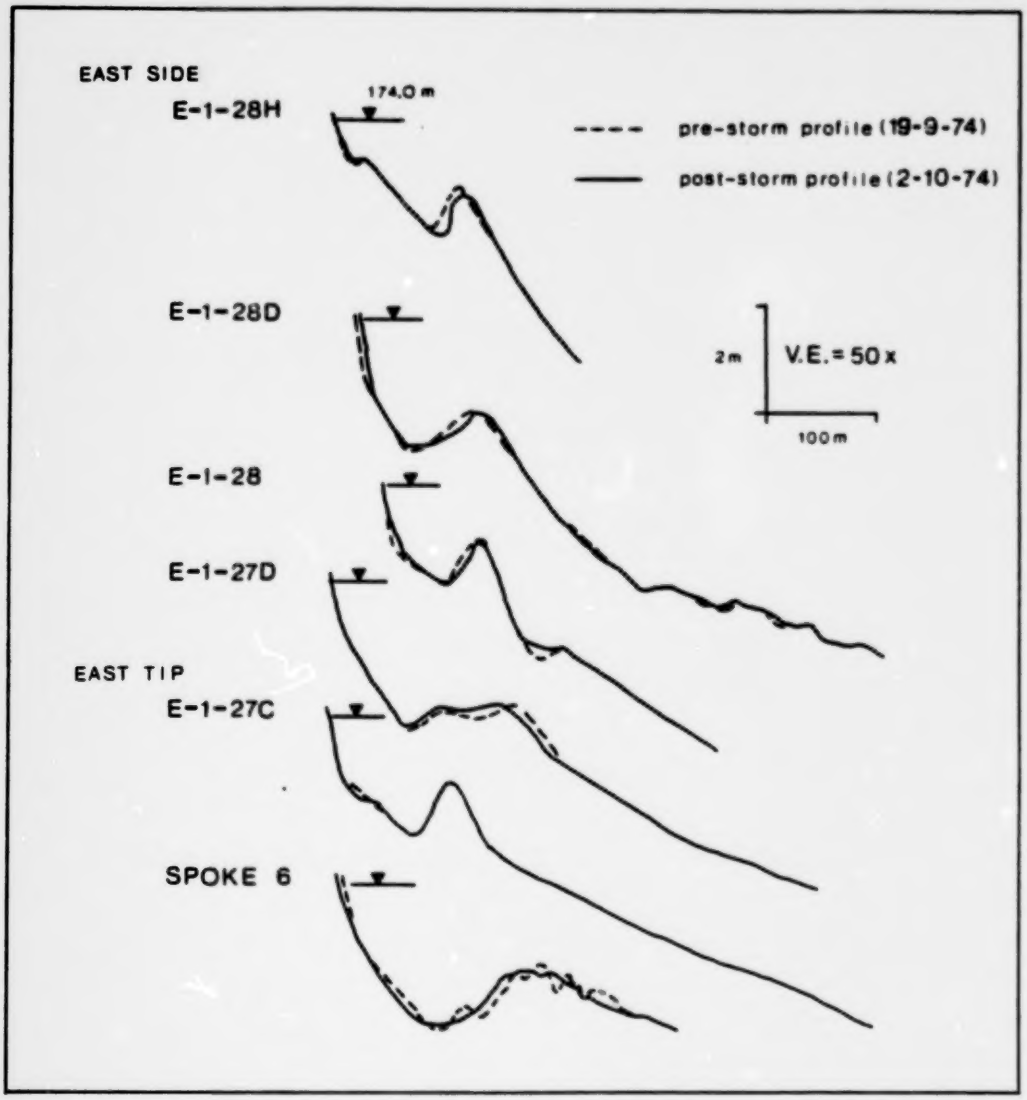

Figure 19. Changes in Nearshore and Offshore Profiles of the East Shore of Point Pelee as a Result of a Westerly Storm on Sept. 29-30, 1974

During the beach monitoring program of 1974 - 1981, the west side of Point Pelee was surveyed about 2 months prior to a moderate easterly storm in mid-Oct. 1975, and again at the end of Oct. (12 days following the storm). The east side was also monitored before the storm, however, 1 month had lapsed before the post-storm survey. Since the east side is effected primarily by easterly storms (see previous section for the effect of a west storm), the survey interval would not likely have a significant impact on the results. Water level records for the Point Pelee gauges indicate that with the exception of the east storm of Oct., and another less intense easterly in Sept., this period was otherwise quiescent. Water levels on the east side reached a maximum differential of 27 cm, as a result of the storm.

Table 14 summarizes the changes in beach and offshore sediments that took place during the months of Sept. and Oct., while Fig. 20-23 show changes in the beach and offshore profiles. In spite of a west storm which produced a differential of 63 cm in Point Pelee lake levels prior to the post-storm survey of the east side, the east beach showed little sign of recovery. Most severe losses occurred at the north end of the Park where 11 m^2 of sediment was eroded from the beach face resulting in a recession of 9 m. Erosion diminished toward the tip but the tip itself lost up to 20 m^2 and receded as much as 10 m. None of the beach material at the northerly reach was transferred inland but there is some indication that this may have occurred at the tip (Fig. 20). For the stations having offshore data, it appears that beach sediments were transferred to the nearshore and offshore to depths of about 4 m (Fig. 21). Erosion at the tip extended into the offshore to depths of 6 m.

Of most relevance to the idea of sediment transport around the

TABLE 14

CHANGES IN BEACH, NEARSHORE AND OFFSHORE PROFILES AS THE RESULT OF AN EASTERLY STORM ON OCT. 17-18, 1975.*

WEST PELEE				EAST PELEE			
Erosion/Deposition (m^2)							
STATION	Beach	Nearshore	Offshore	STATION	Beach	Nearshore	Offshore
West Side				East Side			
E-1-25	<1	<1	50	E-1-30	-11	-15	4
E-1-26	<1	19	63	E-1-28H		(no data)	
E-1-26D	<1	6	59	E-1-28D		(no data)	
E-1-27	<1	12	122	E-1-28	- 5	23	-6
E-1-27A	<1	1	44	E-1-27D	< 1	(no data)	
West Tip				East Tip			
E-1-27B	6	9	61	E-1-27C	- 5	29	38
SPOKE 1	15	20	< 1	SPOKE 6	-20	(no data)	
Recession/Accession (m)							
West Side				East Side			
E-1-25	<1	3	N/A	E-1-30	- 9	-18	N/A
E-1-26	<1	7	N/A	E-1-28H		(no data)	
E-1-26D	1	-1	N/A	E-1-28D		(no data)	
E-1-27	<1	32	N/A	E-1-28	- 3	7	N/A
E-1-27A	1	1	N/A	E-1-27D	1	(no data)	
West Tip				East Tip			
E-1-27B	5	6	N/A	E-1-27C	- 3	15	N/A
SPOKE 1	15	-3	N/A	SPOKE 6	-10	(no data)	

* Negtive values indicate erosion or recession.

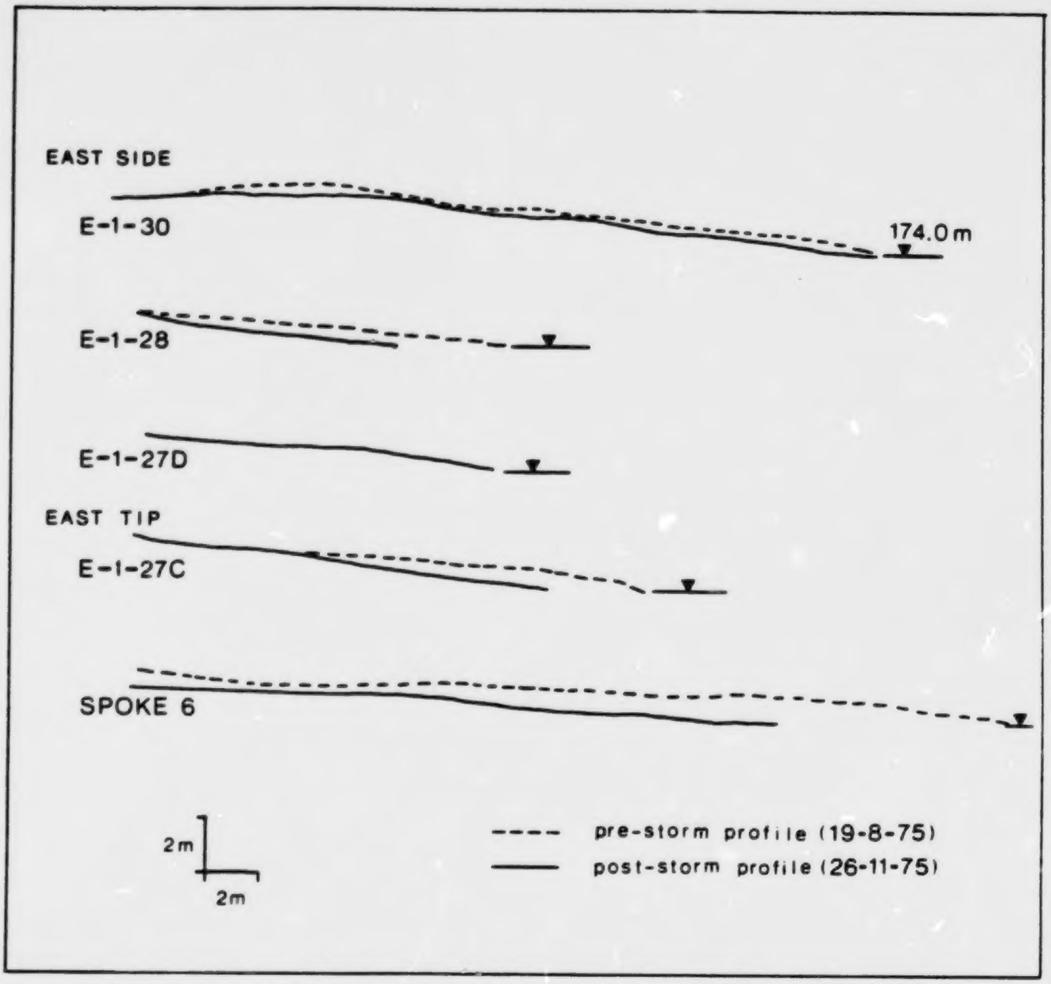

Figure 20. Changes in Beach Profiles of the East Shore of Point Pelee as the Result of an Easterly Storm on Oct. 17-18, 1975

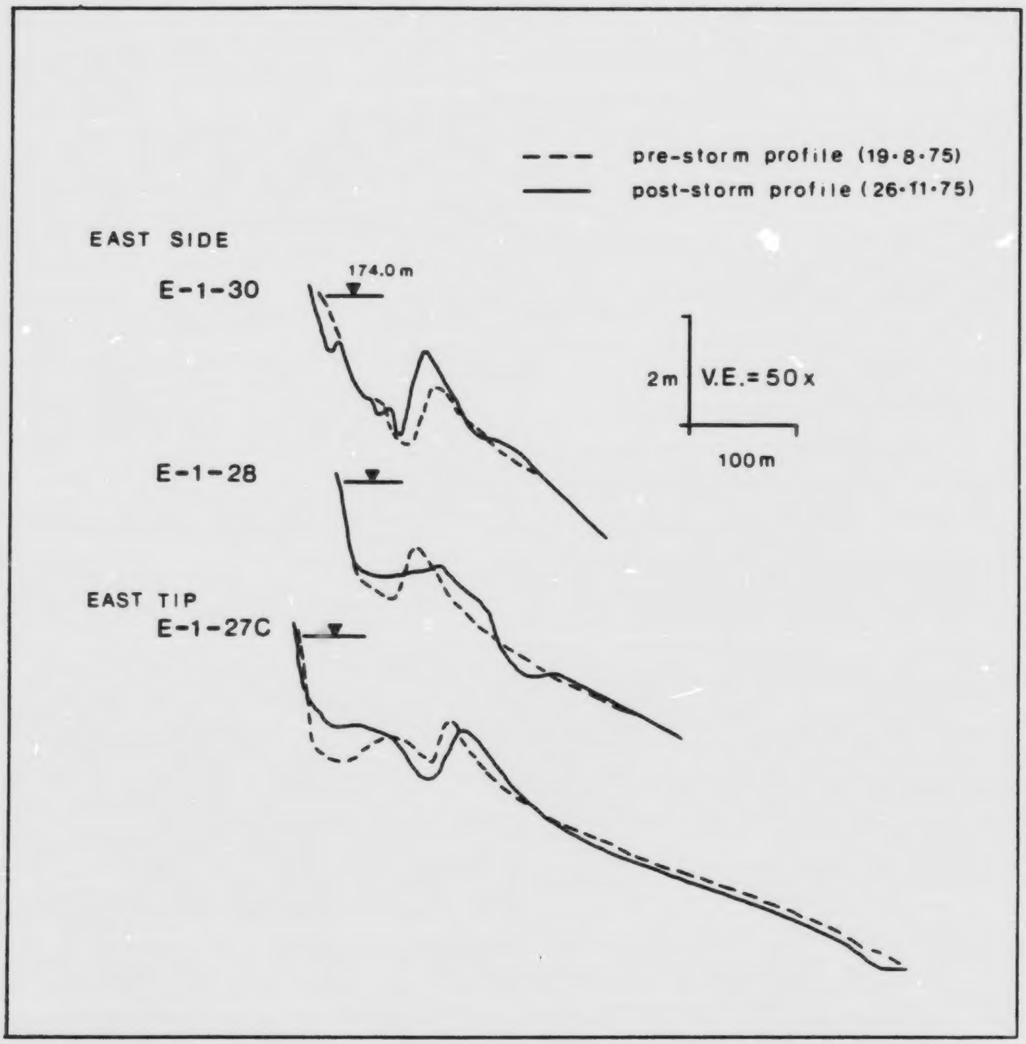

Figure 21. Nearshore and Offshore Profiles of the East Shore of Point Pelee as the Result of an Easterly Storm on Oct. 17-18, 1975

tip, is the response of the west shore to the east storm. The west tip beach gained considerably, as evidenced by an accumulation of 6 - 15 m^2, and a lakeward advance of 5 - 15 m (Table 14 and Fig. 22). North of the tip, beach profiles showed negligible gains of a fraction of a metre. Although deposits did not appear to effect the beach much beyond the WEST TIP, nearshore and offshore profiles show gains for most of the west side (Table 14 and Fig. 23). Maximum accumulation of 166 m^2 was observed about 2.5 km north of the tip at E-1-27.

Another aspect of beach erosion along the east side of Point Pelee is the process of breach formations. The author is not aware of any information on the process of breaching at Point Pelee, other than a collection of photographs taken by Park staff. While these provide a valuable record of breaching episodes, further field study is required to assess their effect on the sediment budget of the east beach. Examples of breach sites at Bush Pond and Lake Pond are shown in Fig. 24.

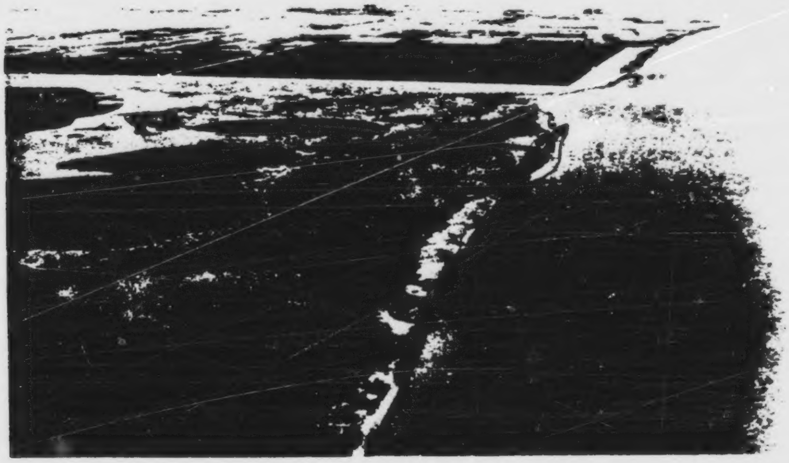

Fig. 24. Breach at Lake Pond (foreground) and Bush Pond (background). (Photo credit: D. Wigle, Point Pelee National Park, Mar. 1976)

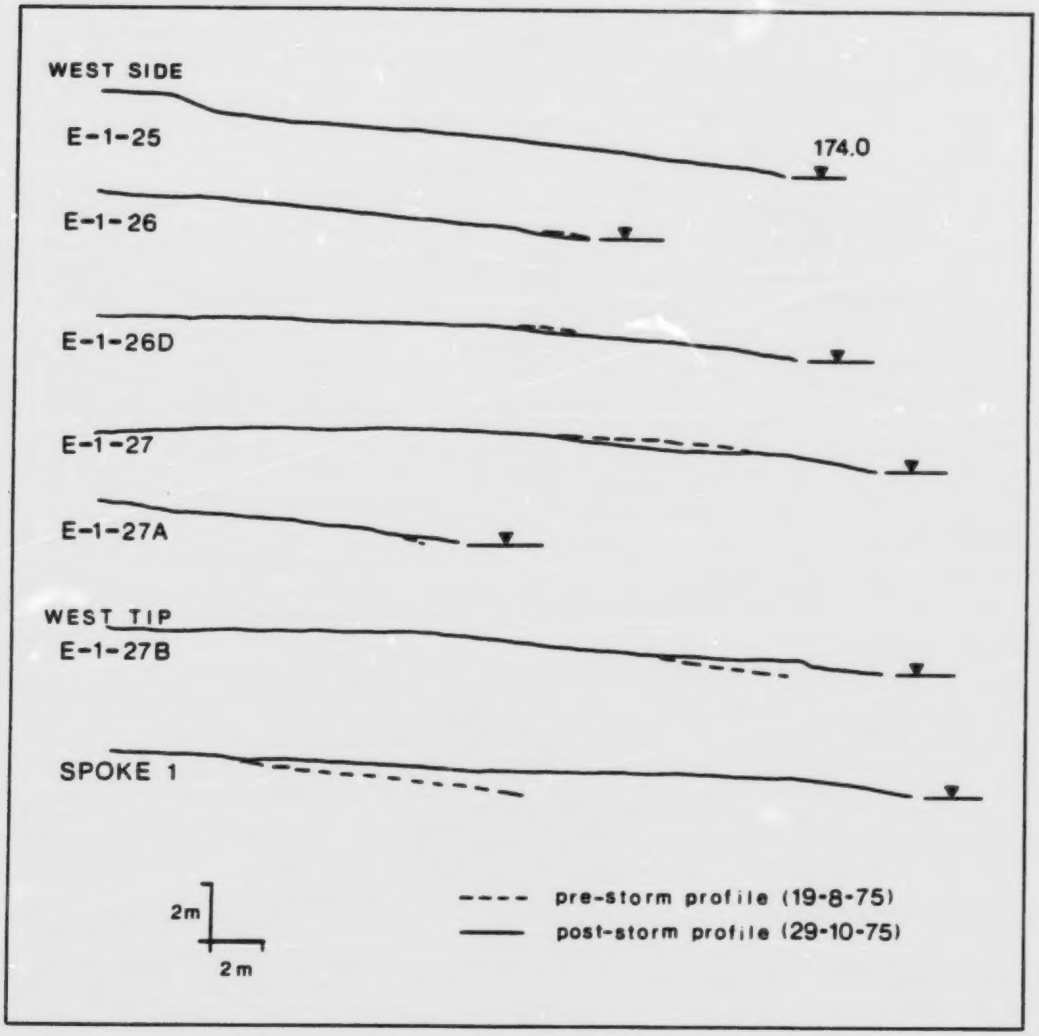

Figure 22. Changes in Beach Profiles of the West Shore of Point Pelee as the Result of an Easterly Storm on Oct. 17-18, 1975

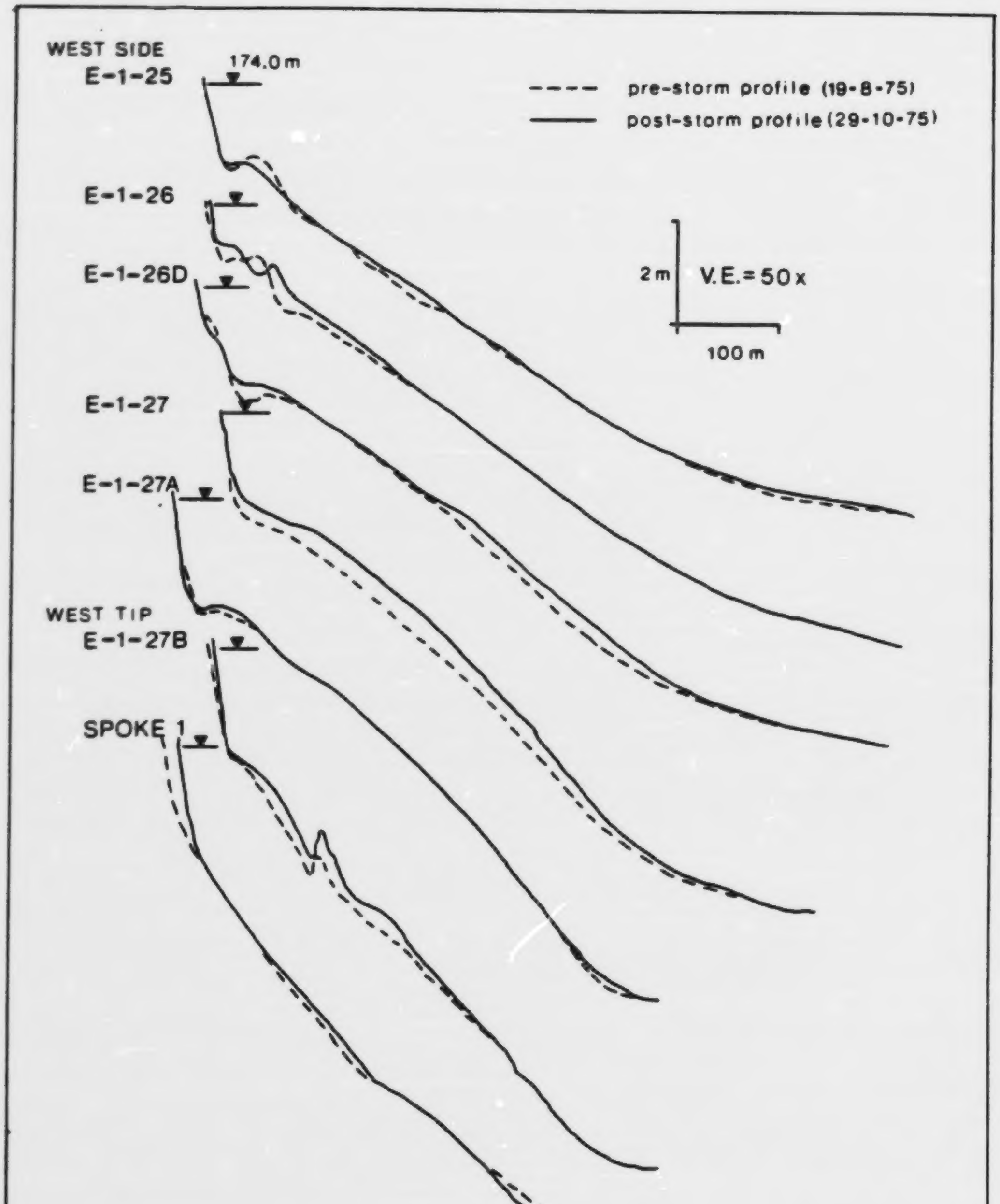

Figure 23. Changes in Nearshore and Offshore Profiles of the West Shore of Point Pelee as the Result of an Easterly Storm on Oct. 17-18, 1975.

5.3 Offshore Dredging as a Process Element in Beach Dynamics.

The removal of offshore sand and gravel deposits on a commercial scale has had a long history at Point Pelee. Licenced areas for dredging have included the subaerial and submerged tip of Point Pelee, to the more recent area on the shoal, about 3 km to the south of the tip. Since 1965, it is reported that up to 267,000 m^3 were being extracted annually (Coakley, 1977). Because of the concern for the extensive erosion to the east beach of Point Pelee in the early 1970's, permits to remove sand and gravel were suspended in 1974 by an injunction under the Beach Protection Act of Ontario. In the interim, studies of shore processes were to be undertaken to resolve the significance of these mining activities.

Results of short-term field investigations were not conclusive, however, they recommend that dredging not take place in northern areas of the shoal, as this area was postulated to be a source of sediments to Point Pelee. Bottom currents measured on the shoal indicated that under certain lake conditions, currents flow northward toward the Point at velocities capable of transporting sand-sized sediment (Coakley 1977 and Shaw 1978).

Offshore dredging activities also alter the morphology of the lake bed. Although the origin of a 10 m deep trench that enters the area licenced for dredging has not been verified, such features potentially effect the sediment dynamics at Point Pelee by creating a sediment sink in the lake bed (Fig. 25). With the suspension of dredging activities, infilling of the trench would be an indication that it was likely man-made.

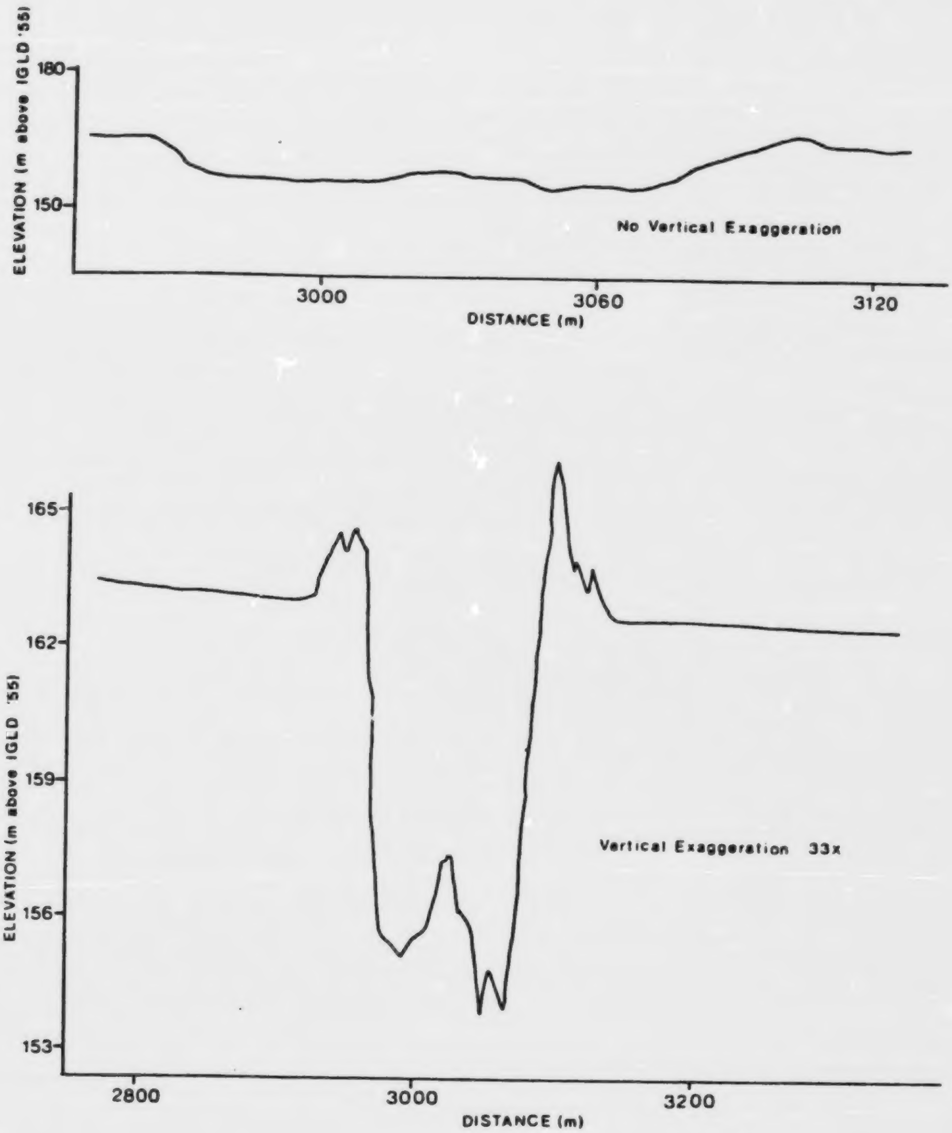

Figure 25. Trench in Lake Bed of Lake Erie South of Point Pelee (Shaw 1978)

Extensions of Spokes 1 and 2 intersect the trench at about 3 km offshore. The results of the sounding surveys are presented as annual averaged volumes in Table 15. In combining the profile data, trench infilling has occurred at an annual rate of about 32 m^2, and with a net gain from 1974 to 1980 of 192 m^2. This trend generally prevailed except for the period of 1975-76 when the trench floor eroded, and again during 1977-78 (Spoke 1 only). At this rate of infilling, the trench will not be erased from the lake bed until the year 2025.

	SPOKE 1	SPOKE 2
1974-75	57	143
1975-76	-105	-181
1976-77	81	7
1977-78	- 98	93
1978-79	103	73
1979-80	49	74
1974-80	174	209

Table 15. Profile Changes (m^2) to the 10 m Deep Trench 3 km to the South of Point Pelee.

Limits of accuracy are definitely a factor with this data, as the accuracy of positioning the sounding vessel becomes more difficult as the distance from shore increases. As an example, a siting error of 1 degree on the transit results in a positioning error of 6 m at a distance of 300 m offshore, but at a distance of 3 km, the sounding vessel would be 52 m offline. In addition, it is not possible to apply a closure depth to these profiles, as the shoal is generally considered to be a mobile bedform. However, if changes were due to sounding errors, the [illegible] should not be bias toward negative or positive values. In contrast, the data indicate there was a positive, or infilling, trend.

Infilling of the trench suggests that past dredging activities are likely related to its origin, and that it is a sediment sink. The relevance to the sediment budget of Point Pelee would appear to be minor, however, in view of the rates of infilling, and relative to the volumes of sediments in the primary storage area of the submerged tip of the spit.

As a conclusion to this section, dredging should definitely not be permitted within the primary storage area for sediments that nourish the beaches and shoal of Point Pelee. This is the submerged tip of the spit to a distance of about 1800 m. In order to ensure this source of sediment is not interfered with by future dredging activities, a buffer zone of 1 km should also be included to the restricted area. Sand and gravel operators would therefore be prevented from mining these resources within 2.8 km of the tip of Point Pelee. While mining beyond this distance is not likely to have a significant impact, these activities should be monitored closely.

5.4 Sediment Budget

The sediment budget of Point Pelee is based on the averaged annual profile data presented in Section 5.1. Changes in profile area (m^2) are multiplied by the length of shore that is represented by the survey station. Reach lengths were established from information recorded during a ground reconnaissance and low altitude airphoto interpretation. Reach lengths are given in the summary tables of the profile data in

Section 5.1. A different method is used to calculate volumes of sediment for the area covered by the spoke network of survey lines that pivot from a fixed point around the tip of the spit. Rather than a reach of shore, the area between spoke survey lines was calculated, and multiplied by the volumetric change per linear metre.

Table 16 summarizes the annual sediment budgets and the net change for the survey period 1974 - 1980. The trend of a westward migrating Point Pelee is evident with an averaged annual net gain for the WEST SIDE shore of 133 $m^3 \times 10^3$, as compared to an annual loss of 202 $m^3 \times 10^3$ for the EAST SIDE. As an indication of the rate of westward migration, erosion of the east beach averaged about 5 times what the west beach is accumulating. However, this is largely as a result of the excessive erosion following the high lake levels of 1973. Erosion since 1977 has been about 6% of what it was during the initial years of the survey, with some years showing net accumulation. The tip of Point Pelee averaged gains of 11 and 42 $m^3 \times 10^3$ per year for the west and east sides respectively, for a combined net gain of 317 $m^3 \times 10^3$.

Overall, the combined sediment budgets of the beach and offshore zones of Point Pelee show an annual net loss of about 16 $m^3 \times 10^3$ of material. Sediment budgets rarely balance, and estimating reach lengths is probably one of the most important factors effecting calculations of the sediment budget using this method. Other estimates of the budget at Point Pelee have been made, but are generally not comparable because of the different techniques used. For example, St. Jacques et al (1976) calculate a sediment budget based on the age and thickness of deposits of the shoal that indicate annual increments of 63 - 126 $m^3 \times 10^3$. In another study, Skafel (1975) used hindcast modelling techniques to estimate longshore transport rates for Point Pelee. The annual

TABLE 16

ANNUAL SEDIMENT BUDGETS 1974-1981*

POINT PELEE

	WEST SIDE			EAST SIDE		
	Offshore	Nearshore	Beach	Beach	Nearshore	Offshore
1974-75	- 25.0	-284.9	17.1	-214.8	-446.2	-112.4
1975-76	380.4	198.0	15.3	-193.6	- 79.1	-121.2
1976-77	-292.8	30.5	10.9	- 90.6	-242.9	- 40.6
1977-78	589.5	337.4	.3	- 12.8	230.3	246.8
1978-79	-123.0	-364.0	17.1	36.6	162.2	- 89.8
1979-80	134.1	130.0	28.7	- 13.0	-338.7	- 69.4
1980-81	-422.5	-173.7	13.5	55.3	89.1	- 60.0
(1974-81	240.7	-126.7	102.9	-432.9	-625.3	-246.6)
1974-80	**663.2**	**47.0**	**89.4**	**-488.2**	**-536.2**	**-186.6**
	WEST TIP			EAST TIP		
1974-75	- 16.2	- 43.5	- 1.8	2.9	41.7	16.2
1975-76	- 5.4	67.3	- .3	- 4.9	- 44.9	- 23.9
1976-77	- 38.3	- 47.9	- .8	4.6	2.0	24.1
1977-78	54.2	48.9	.9	6.1	29.1	27.2
1978-79	19.7	- 4.4	.5	3.4	20.2	3.6
1979-80	- 22.8	51.3	- 6.0	- 1.6	67.2	- 11.8
1980-81			(no data)			
1974-80	**2.0**	**71.7**	**- 7.5**	**10.5**	**205.1**	**35.4**

* Sediment budgets are calculated using annual averages.
Negative values indicate erosion.
Volumes are expressed in $m^3 x10_3$.

longshore transport rate for the east side was estimated to be 26 m^3 x 10^3. Another factor effecting the comparability of estimates of the sediment budget is that the profile method represents changes in the short-term, whereas coring and modelling techniques generally reflect long-term conditions (e.g. since deglaciation).

6.0 CONCLUSIONS AND IMPLICATIONS

The understanding of shore processes at Point Pelee has been advanced significantly from recent intensive but short-term studies (e.g. one season) of process elements including sediments, waves and currents. These studies have led to hypotheses of sediment transport processes and causes of erosion but have never been tested with appropriate field data.

This report is aimed at complementing the existing knowledge of shore processes by providing some of the data needed to substantiate these hypotheses. Under a federally funded monitoring project, erosion to the beach and offshore zones of Point Pelee National Park was surveyed from 1974-1981. Surveys extended to the offshore limits of the sand deposits, and covered the submerged tip of the spit to a distance of 3 km. Based on the series of onshore and offshore profiles, a geomorphological approach was used for the interpretation of the shore processes. This data quantifies sediment transfer between the shore zones of Point Pelee and defines the limits of sediment transport and storage in the offshore zone. Using this information, a more definitive assessment of the impacts of dredging is also possible.

Conclusions

As a result of this study, are the following conclusions regarding shore processes at Point Pelee:

(i) The shores of Point Pelee are continuing to migrate westward at an average rate of about 1 m/yr for the west shore, and about 4 m/yr for the east shore. At an average loss of 3 m/yr to the width of the Point, as indicated in this study, the land area of the National Park could be reduced substantially. Uninterrupted, the Park will be eroded into the lake in 1500 years.

(ii) Erosion of the east beach diminished significantly since 1976. Volume losses indicate rates of erosion at about 10% of those recorded for the two to three year period following the high lake levels of 1973.

(iii) Rates of erosion are also more evenly distributed along the east beach since 1976. This suggests factors other than high lake levels were affecting rates of erosion at the north east corner of the Park (e.g. groynes).

(iv) Changes in offshore volumes illustrate the relative insignificance of the beach sediment in terms of the overall sediment budget of the shoreface. Beach volumes represent about 3% of offshore sediments on the west side, and about 12% on the east side.

(v) In comparing the nearshore profiles of the sides of the Point with that of the tip, there is a direct relationship between erosion of the shores of Point Pelee with accumulations at the tip. The bulk of this material accumulates on the submerged tip to a distance of 1,800 m.

(vi) Profile data support a sediment transport model that suggests westward migration is in large part due to the transfer of sediment from the east side during easterly storms. As a result of a moderate east storm, the west tip beach gained sediments at a time when erosion was the predominating trend.

(vii) Infilling of the 10 m deep trench to the south of the Point suggests its origin is related to past dredging activities. Rates of infilling (32 $m^3/m/yr$) indicate that it will not be until the year 2025 before the trench is filled to the level of the lake bed.

Implications to Research

On the basis of these conclusions, the following short-term and long-term research needs are identified:

(i) The impact of storms requires further research to provide a more complete assessment as to their relative significance in the overall sediment transfer processes at Point Pelee. The network of onshore and offshore profiles should be monitored during spring and fall storms. Profiles should be supplemented with observations of water levels (simultaneously on both sides of the Point), winds and waves for correlating storm classes with rates of sediment transfer. It should also be pointed out that the existing network of stations represents minimum coverage and should be expanded for more accurate results.

(ii) The process of breaching and affects of hydraulic gradients across the beach have not been investigated at Point Pelee, yet breaching is a major factor in the erosion of the Pelee beaches. Breaching generally occurs in the spring months in response to easterly storms. Sections of beach that are prone to breaching (e.g. fronting Lake Pond) should be monitored to determine conditions associated with breach formation and closure. In addition to beach profiling and storm related data, marsh water levels should also be monitored as the surface of the marsh tilts under storm conditions. One approach may be to compare this information with that of ocean breaching processes.

(iii) The need to annually monitor shore changes during rising and falling lake levels is needed to determine the influence of long-term changes in lake level on beach stability. Although low lake levels are generally thought to be associated with low erosion rates, beach and nearshore adjustments during these periods may influence rates of erosion during rising lake levels.

Although these recommendations pertain to Point Pelee, it may be particularly useful to extend these studies to other areas along the north shore of Lake Erie. The inter-relationship of shore processes at Point Pelee with that of Rondeau Point has been studied using remote sensing techniques. To assist in the knowledge of shore processes in this region, research is needed to qauntify and verify such hypotheses. Such research would also lead to a better understanding of beach processes in other areas of the Great Lakes shoreline, especially other spit formations such as Long Point.

Short-term research in shore processes is presently being conducted by universities and government agencies. However, long-term research projects present more of an obstacle as they require long-term resource commitments. Past experience has shown that government agencies are not prepared to make this level of commitment. Research thrusts are strongly influenced by political decisions and are constantly changing in response to new issues (having high public profile), or are directed toward developing solutions to crisis oriented events. It is therefore recommended that jointly funded programs by federal, provincial and municipal governments be initiated to support universities who are equipped to conduct such investigations. This research mandate should be assigned with a cooperative approach as the guiding principle. Cooperative research programs by government and universities would then be working together toward a collective resolve to the many management issues facing the Great Lakes shore.

Implications to Management

As a result of the findings of this thesis, dredging should definitely be restricted from the primary storage area of the submerged tip. This extends from the tip of Point Pelee to a distance of about 1,800 m offshore. In order to ensure this source of sediment is not affected by possible future dredging activities, a buffer zone of 1 km should also be added to the restricted area. Sand and gravel operators would therefore be prevented from mining within a 2.8 km radius of the tip of Point Pelee. The effects of mining beyond this distance has not been sufficiently resolved and, therefore, any future activities should be monitored closely.

Proposals for combatting erosion with the construction of shore structures along Park beach or adjacent beaches should be avoided. Evidence from this thesis showed that shore protection structures were a factor in the erosion processes occurring on the east shore of Point Pelee in particular.

Future research in the areas outlined above will assist in the management of the Point Pelee beaches by providing better insight into the erosion processes affecting Point Pelee. For instance, a better understanding of the impact of storms and the breaching process will enable predictions of where and when damages may be incurred and under what conditions. In addition, processes responsible for the nourishment of Point Pelee beaches will also be better understood. This knowledge could lead to improved management strategies to control erosion losses. For example, it may not be the best policy to artificially close breaches in the beach as these features provide a natural control of the hydraulic forces that are induced by differences in lake and marsh water levels.

The proposed research also has broader implications to the management of Great Lakes shorelines. Data concerning beach and nearshore response to long-term changes in lake level is relevant to engineering applications (e.g. design and installation of shore protective structures), recreation studies (economics of beach recreation) and in the assessment of implementing greater lake level regulation (much of the existing information concerning shore erosion for different lake level stages is based on hypotheses).

In conclusion, it is recommended that shoreline and offshore development proposals at Point Pelee or in the vicinity of the Point be submitted to appropriate government environmental screening mechanisms (e.g. EARP). This not only serves to focus attention on the risks to the environment, but also provides a forum whereby managers and scientists can communicate openly for the development of optimum management solutions.

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APPENDICES

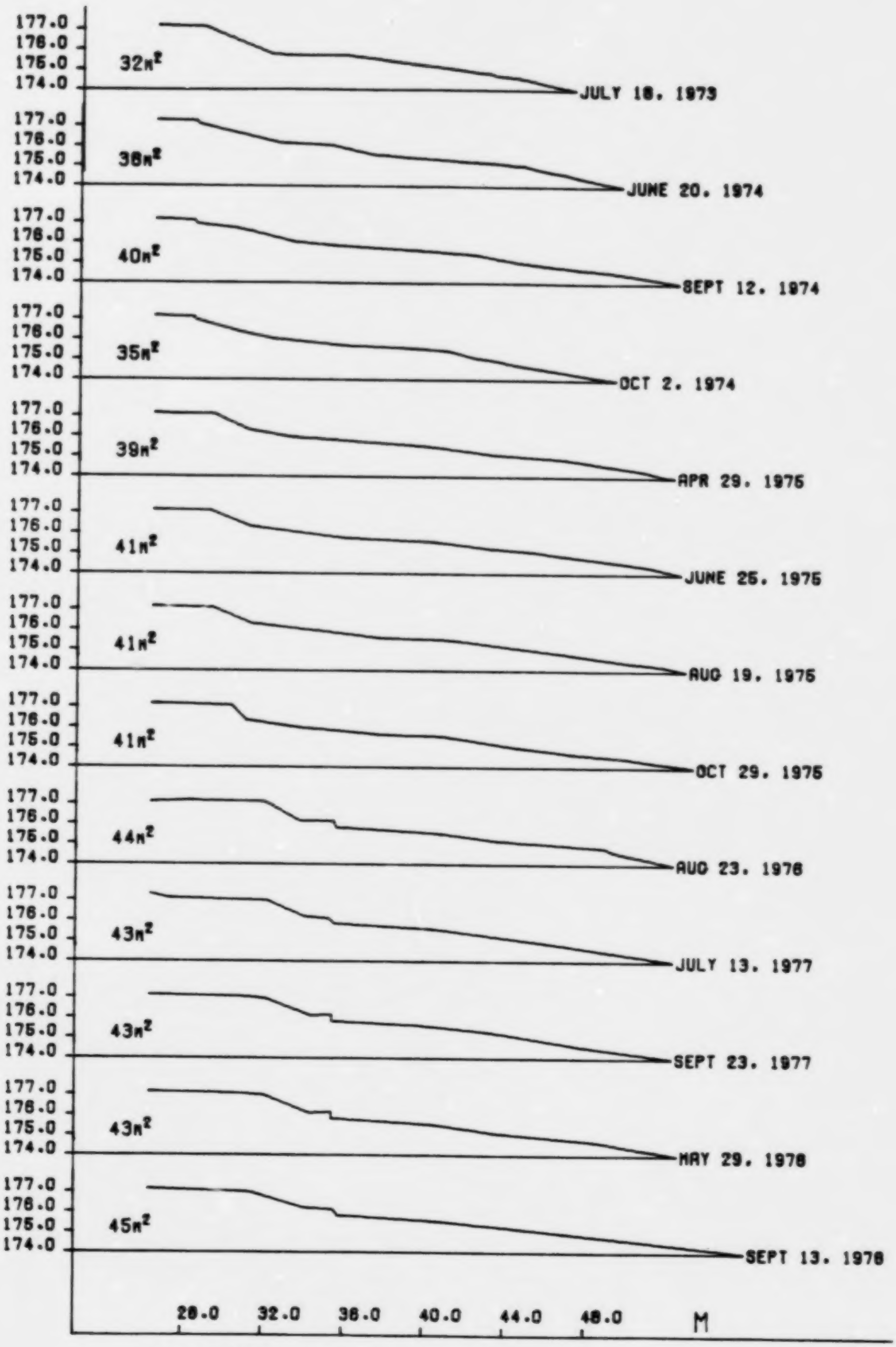
Appendix 1. Beach Profile Plots 1974-1981. 114

Appendix 2. Nearshore and Offshore Profile Plots 1974-1981. 139

Appendix 3. Time-Series Observations of Beach, Nearshore and Offshore Sediment Volumes 1974-1981. 163

APPENDIX 1

Beach Profile Plots 1974-1981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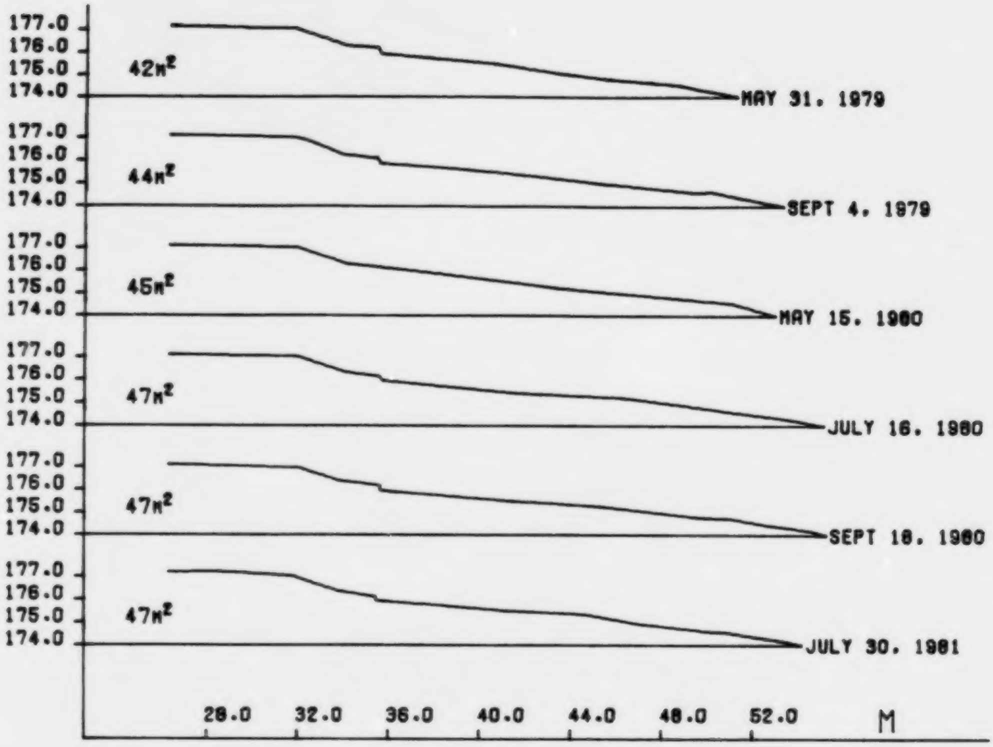
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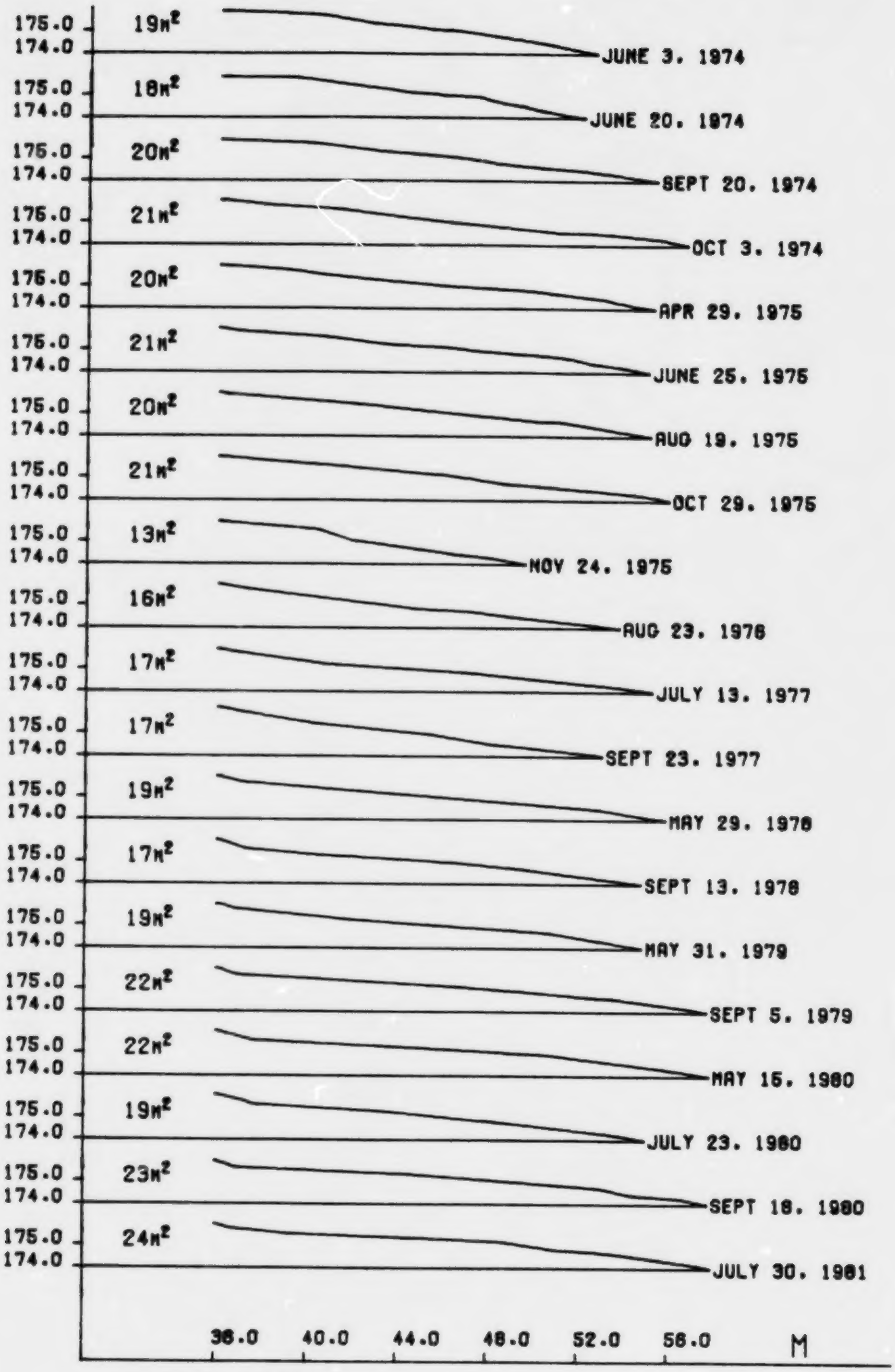
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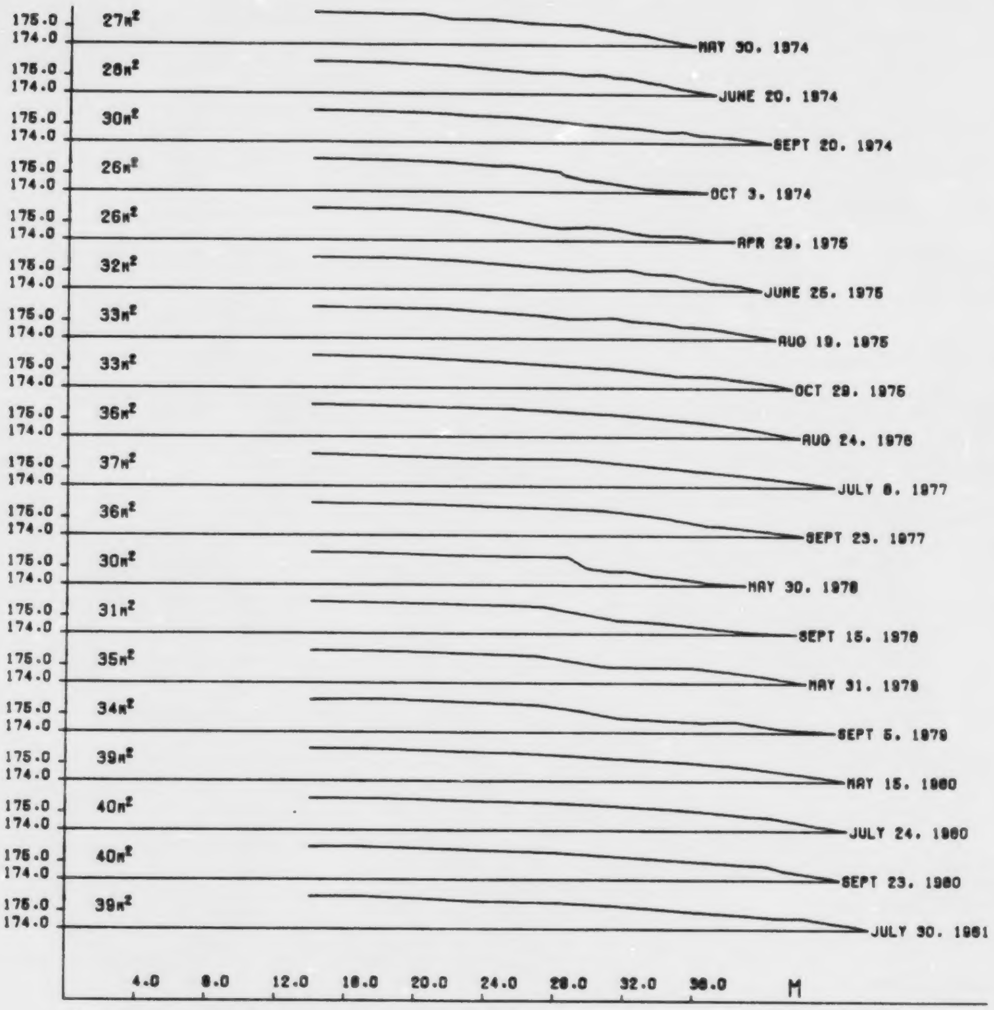
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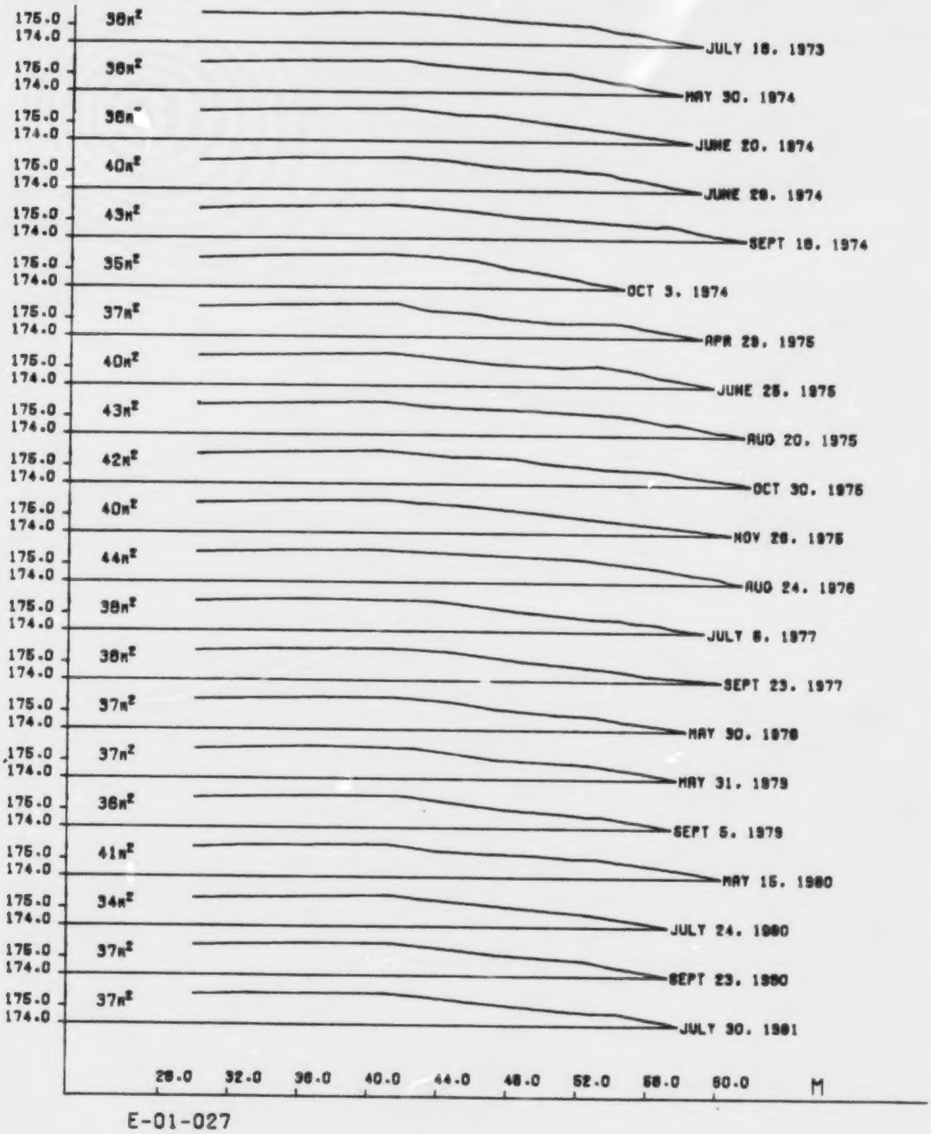
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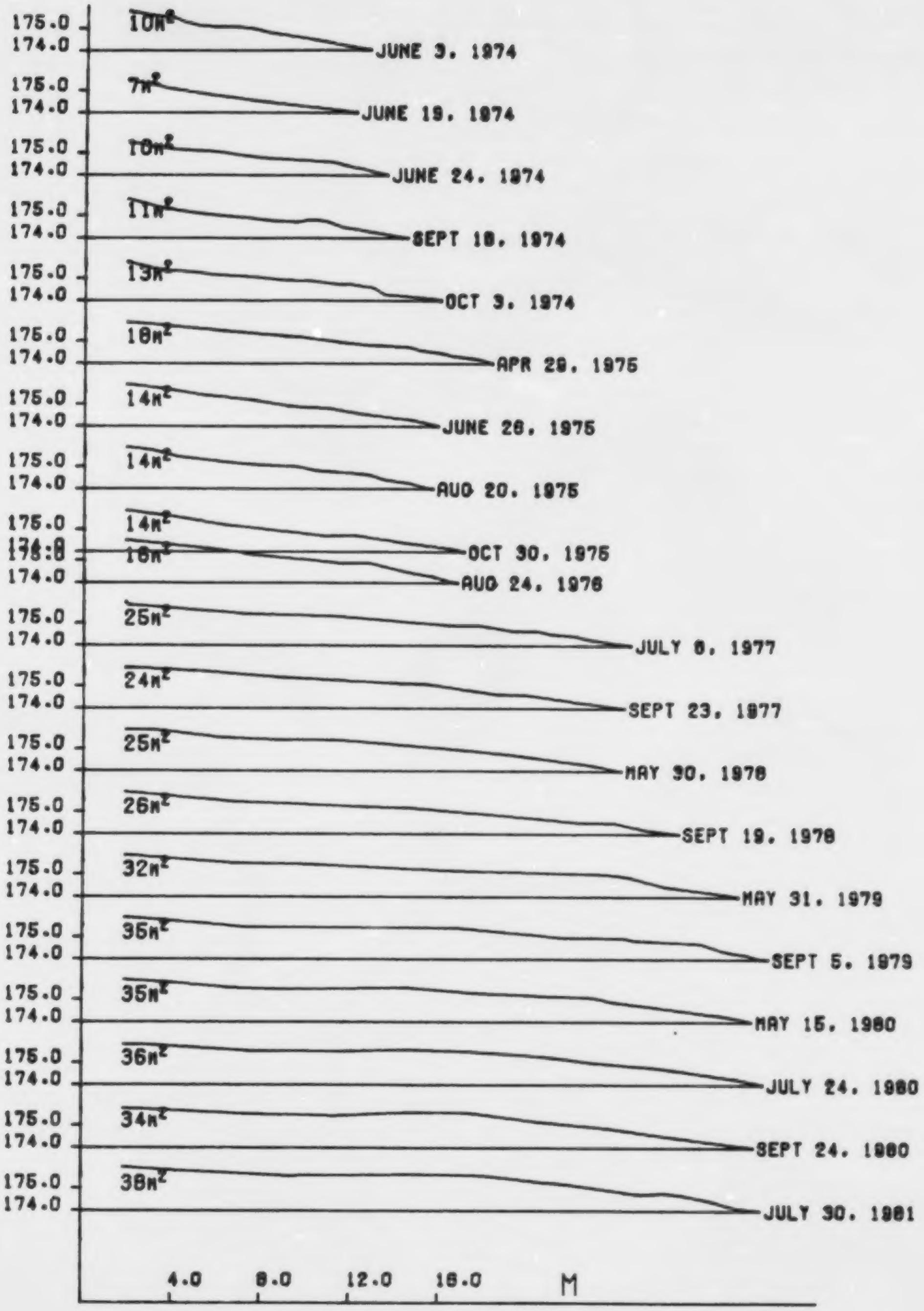
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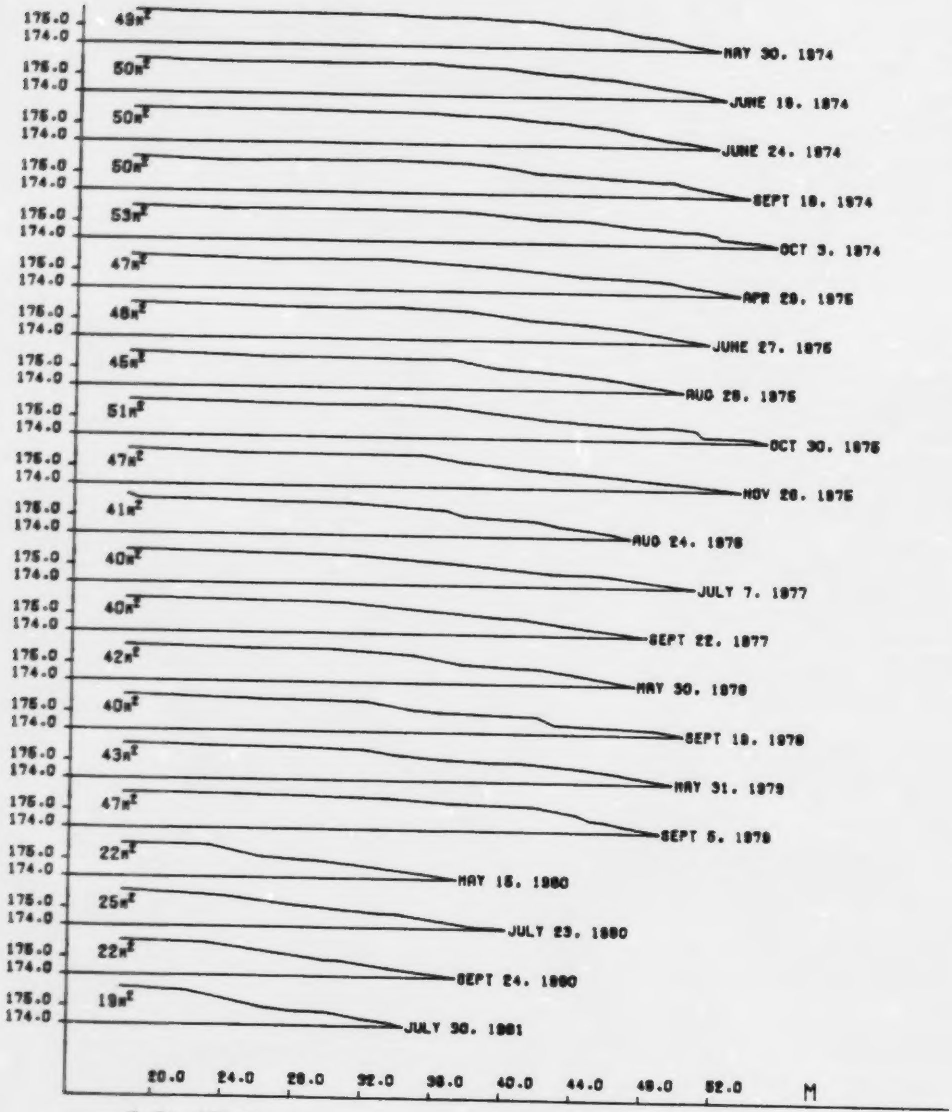
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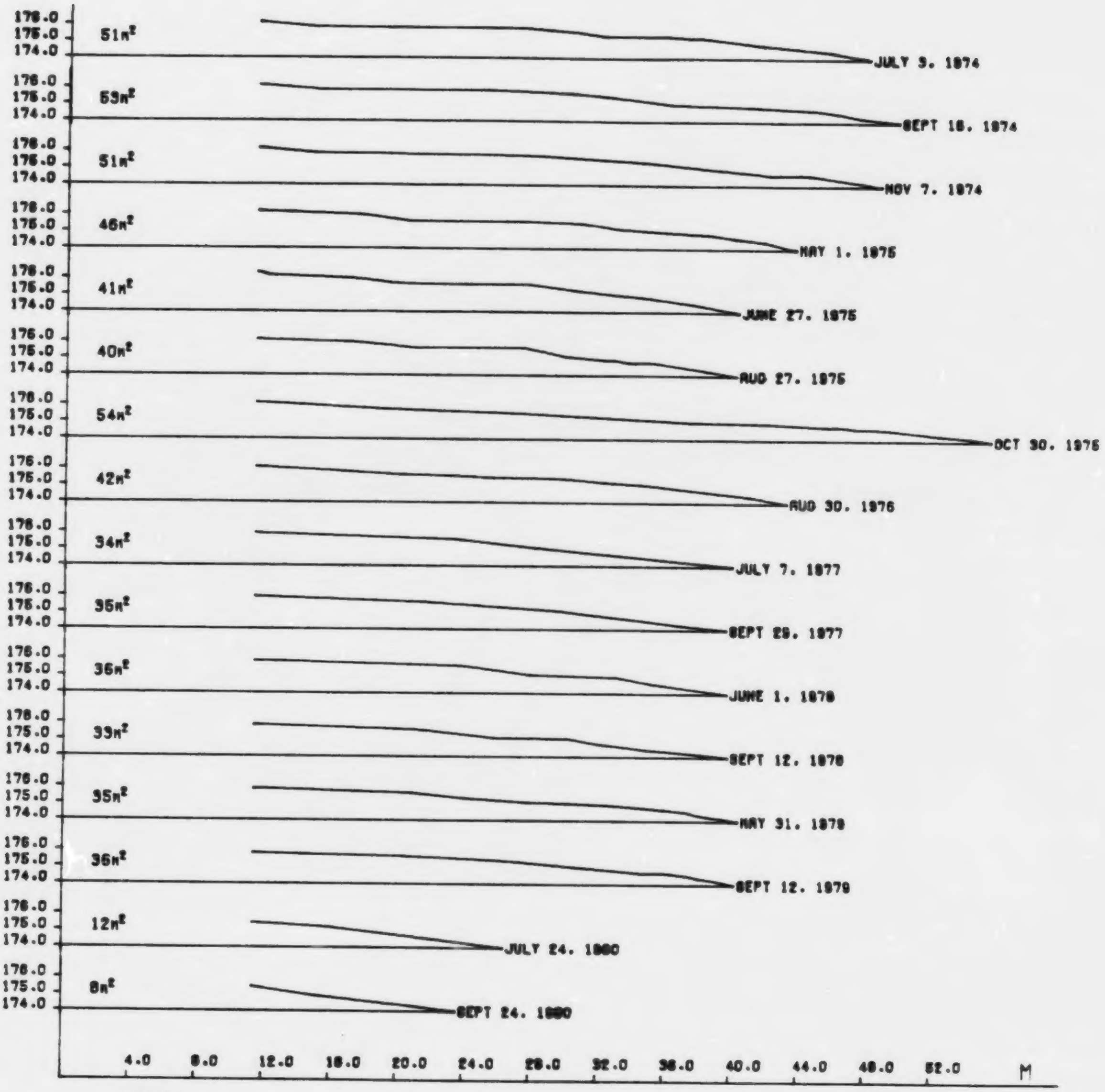
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175.0
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SEPT 18. 1974
51m²
NOV 7. 1974
46m²
MAY 1. 1975
41m²
JUNE 27. 1975
40m²
AUG 27. 1975
54m²
OCT 30. 1975
42m²
AUG 30. 1976
34m²
JULY 7. 1977
35m²
SEPT 29. 1977
36m²
JUNE 1. 1978
33m²
SEPT 12. 1978
35m²
MAY 31. 1979
36m²
SEPT 12. 1979
12m²
JULY 24. 1980
8m²
SEPT 24. 1980
4.0
8.0
12.0
16.0
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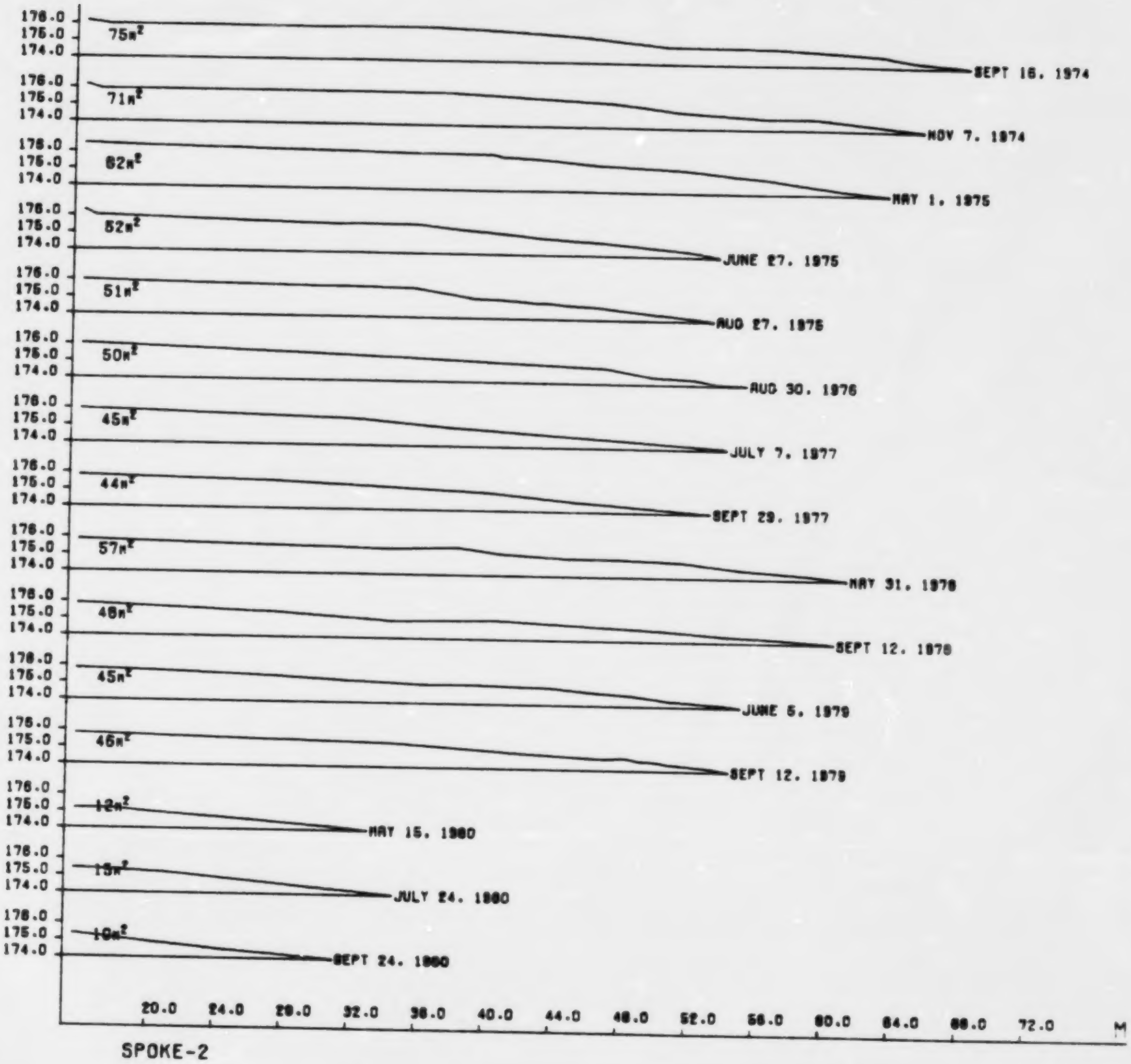
24.0
28.0
32.0
36.0
40.0
44.0
48.0
52.0
M

SPOKE-1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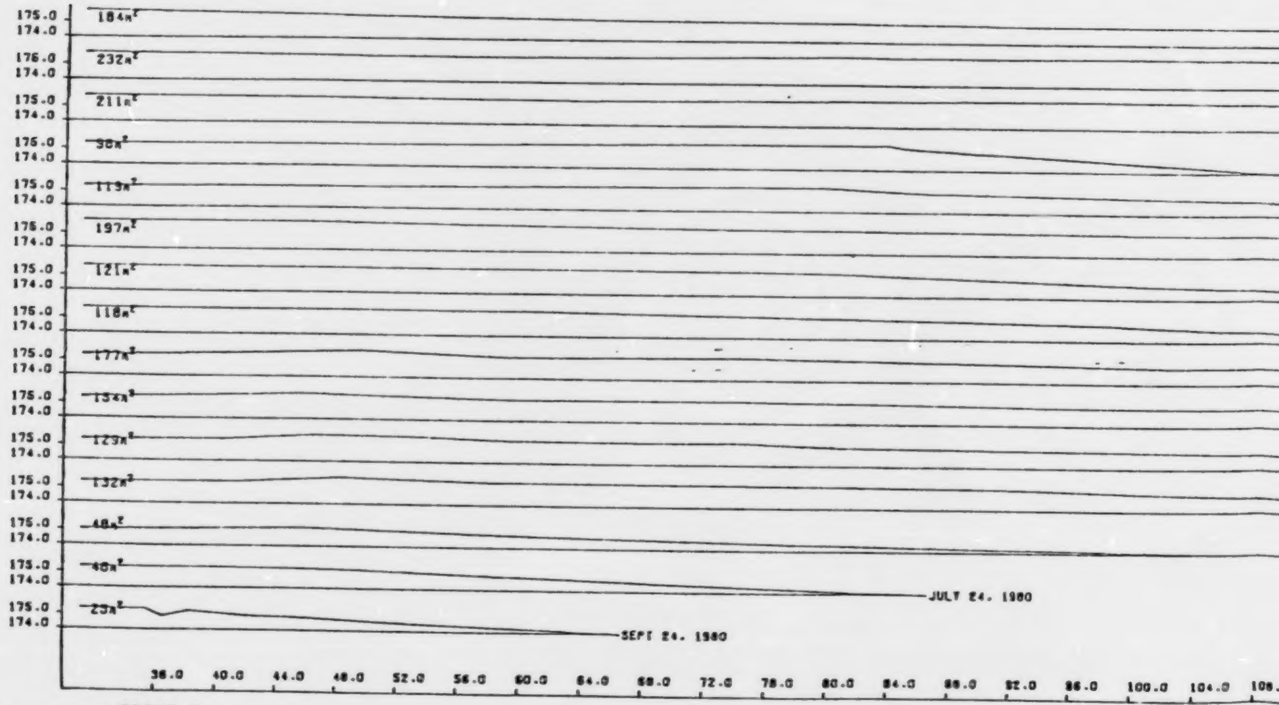
175.0
174.0
75m²
SEPT 16, 1974
71m²
NOV 7, 1974
62m²
MAY 1, 1975
52m²
JUNE 27, 1975
51m²
AUG 27, 1975
50m²
AUG 30, 1976
45m²
JULY 7, 1977
44m²
SEPT 29, 1977
57m²
MAY 31, 1978
48m²
SEPT 12, 1978
45m²
JUNE 5, 1979
46m²
SEPT 12, 1979
12m²
MAY 15, 1980
13m²
JULY 24, 1980
10m²
SEPT 24, 1980
20.0
24.0
28.0
32.0
36.0
40.0
44.0
48.0
52.0
56.0
60.0
64.0
68.0
72.0
M

SPOKE-2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174.0
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174.0
232m^2
175.0
174.0
211m^2
176.0
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30m^2
175.0
174.0
119m^2
176.0
174.0
197m^2
175.0
174.0
121m^2
176.0
174.0
118m^2
175.0
174.0
177m^2
175.0
174.0
134m^2
175.0
174.0
129m^2
175.0
174.0
132m^2
175.0
174.0
48m^2
175.0
174.0
46m^2
175.0
174.0
23m^2
JULY 24. 1980
SEPT 24. 1980
36.0
40.0
44.0
48.0
52.0
56.0
60.0
64.0
68.0
72.0
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80.0
84.0
88.0
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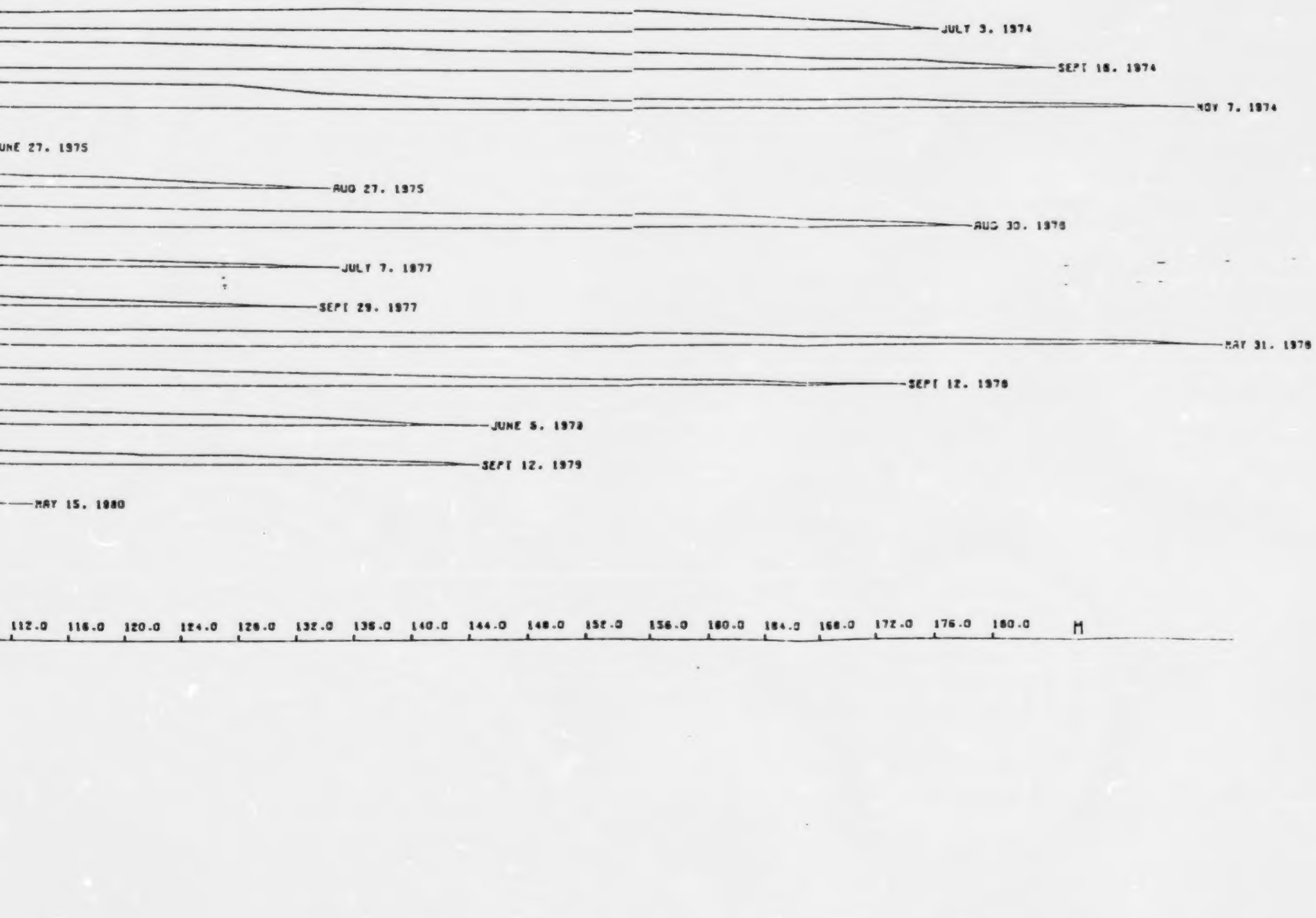
96.0
100.0
104.0
108.

SPOKE-3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SEPT 18, 1974
NOV 7, 1974
UNE 27, 1975
AUG 27, 1975
AUG 30, 1976
JULY 7, 1977
SEPT 29, 1977
MAY 31, 1978
SEPT 12, 1978
JUNE 5, 1979
SEPT 12, 1979
MAY 15, 1980
112.0
116.0
120.0
124.0
128.0
132.0
136.0
140.0
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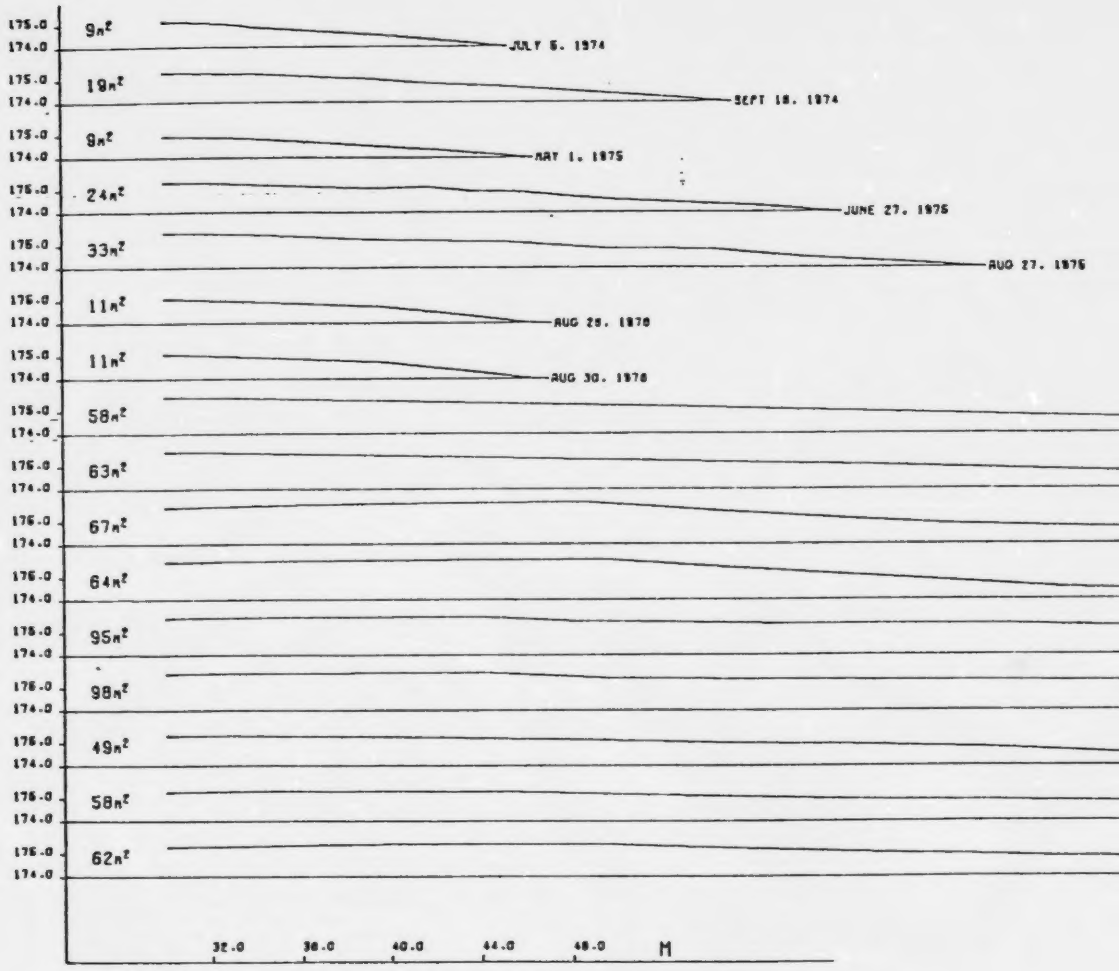
148.0
152.0
156.0
160.0
164.0
168.0
172.0
176.0
180.0
M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174.0
$9m^2$
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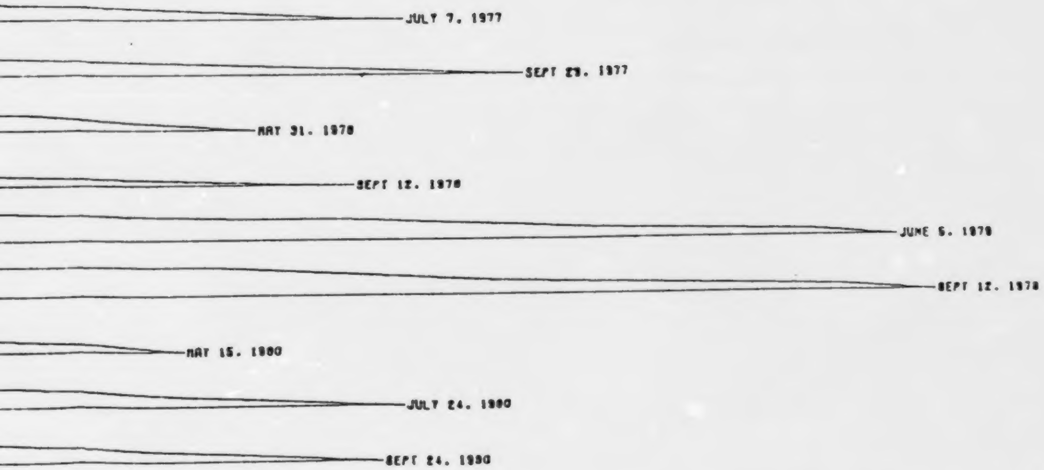
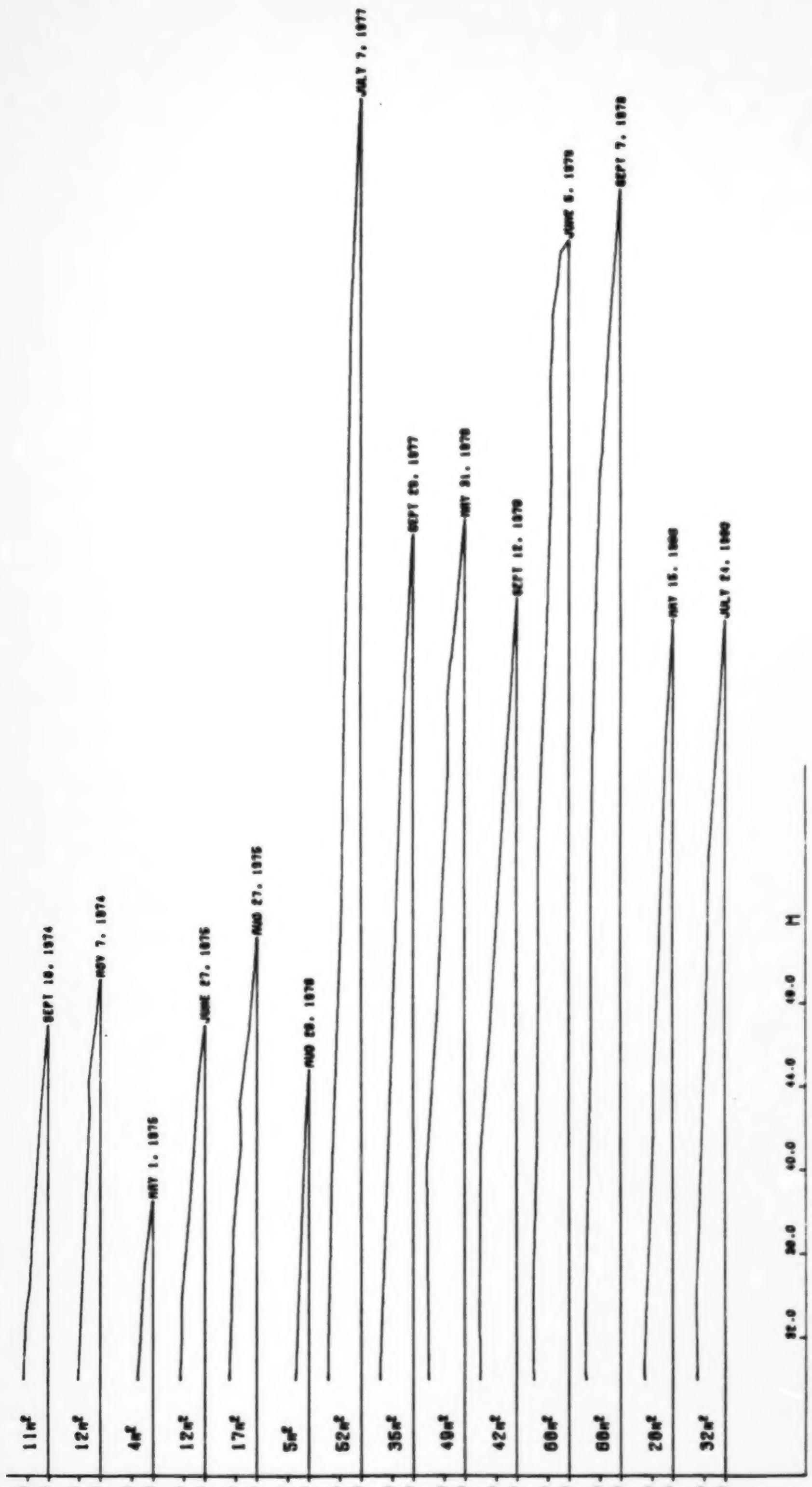
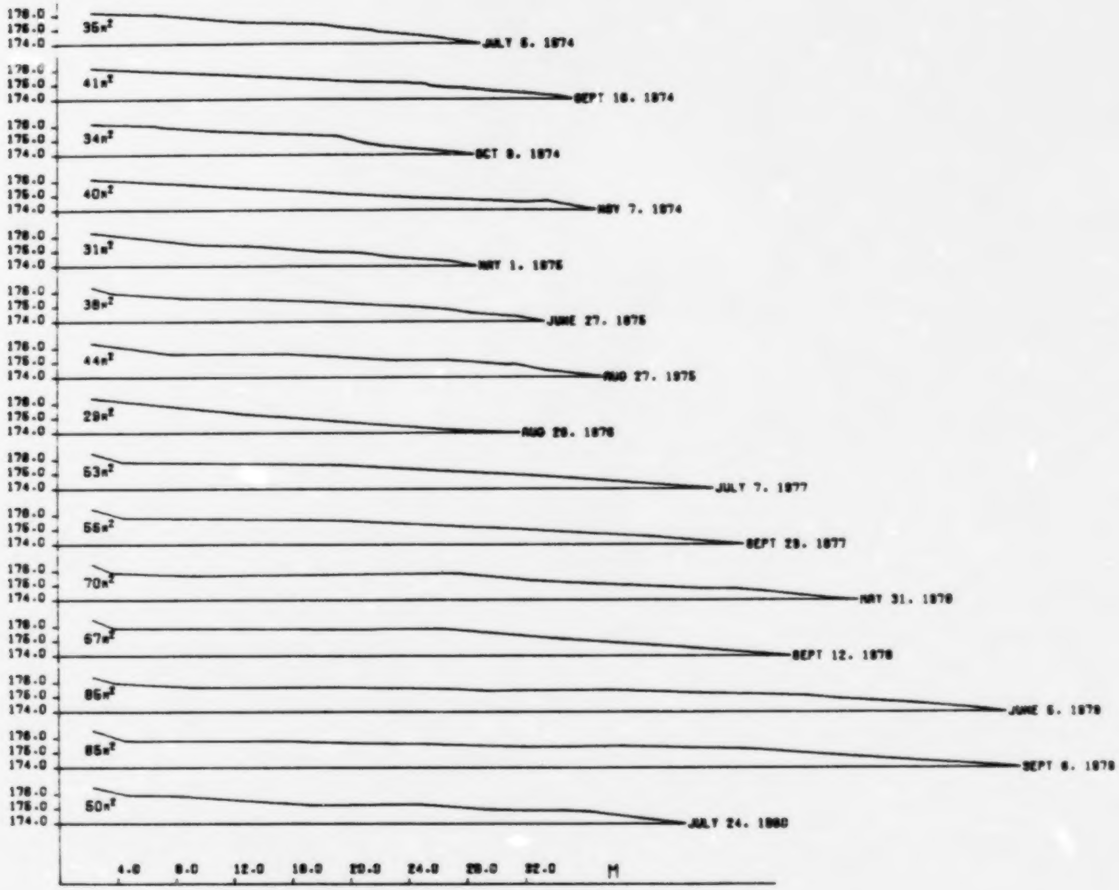
$19m^2$
SEPT 18. 1974
$9m^2$
MAY 1. 1975
$24m^2$
JUNE 27. 1975
$33m^2$
AUG 27. 1975
$11m^2$
AUG 29. 1976
$11m^2$
AUG 30. 1976
$58m^2$
$63m^2$
$67m^2$
$64m^2$
$95m^2$
$98m^2$
$49m^2$
$58m^2$
$62m^2$
32.0
36.0
40.0
44.0
48.0
M

SPOKE-4

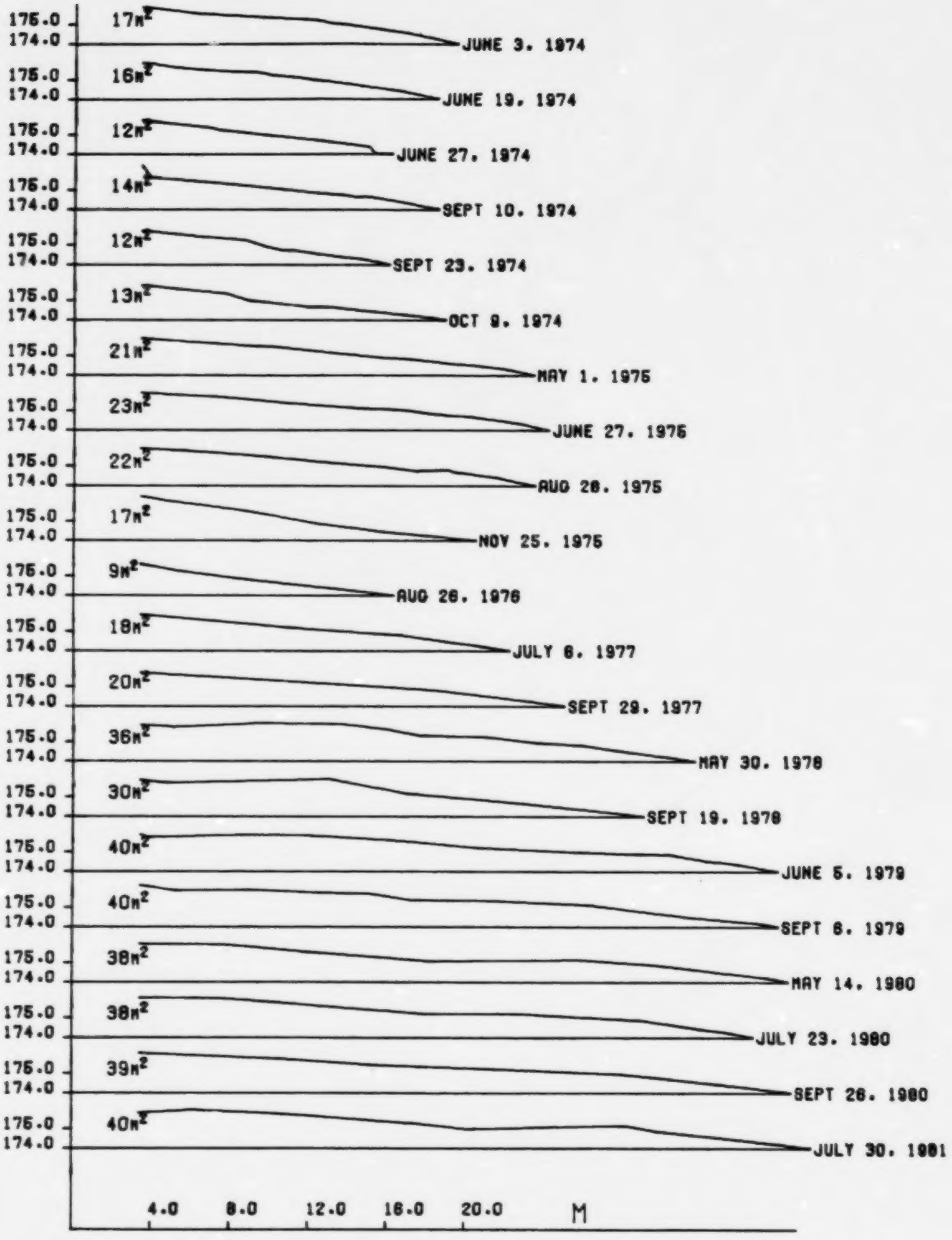

JULY 7, 1977
SEPT 29, 1977
MAY 31, 1978
SEPT 12, 1978
JUNE 5, 1979
SEPT 12, 1979
MAY 15, 1980
JULY 24, 1980
SEPT 24, 1980


SEPT 10, 1974
NOV 7, 1974
MAY 1, 1975
JUNE 27, 1975
AUG 27, 1975
AUG 25, 1976
JULY 7, 1977
SEPT 29, 1977
MAY 31, 1978
SEPT 12, 1978
JUNE 5, 1979
SEPT 7, 1979
MAY 15, 1980
JULY 24, 1980
11m²
12m²
4m²
12m²
17m²
5m²
52m²
35m²
40m²
42m²
60m²
60m²
20m²
32m²
175.0
174.0
32.0
36.0
40.0
44.0
48.0
M

SPOKE-5


178.0
176.0
174.0
35m²
JULY 5. 1974
41m²
SEPT 18. 1974
34m²
OCT 9. 1974
40m²
NOV 7. 1974
31m²
MAY 1. 1975
38m²
JUNE 27. 1975
44m²
AUG 27. 1975
29m²
AUG 28. 1976
53m²
JULY 7. 1977
56m²
SEPT 29. 1977
70m²
MAY 31. 1978
67m²
SEPT 12. 1978
86m²
JUNE 5. 1979
85m²
SEPT 6. 1979
50m²
JULY 24. 1980
4.0
8.0
12.0
16.0
20.0
24.0
28.0
32.0
M

SPOKE-6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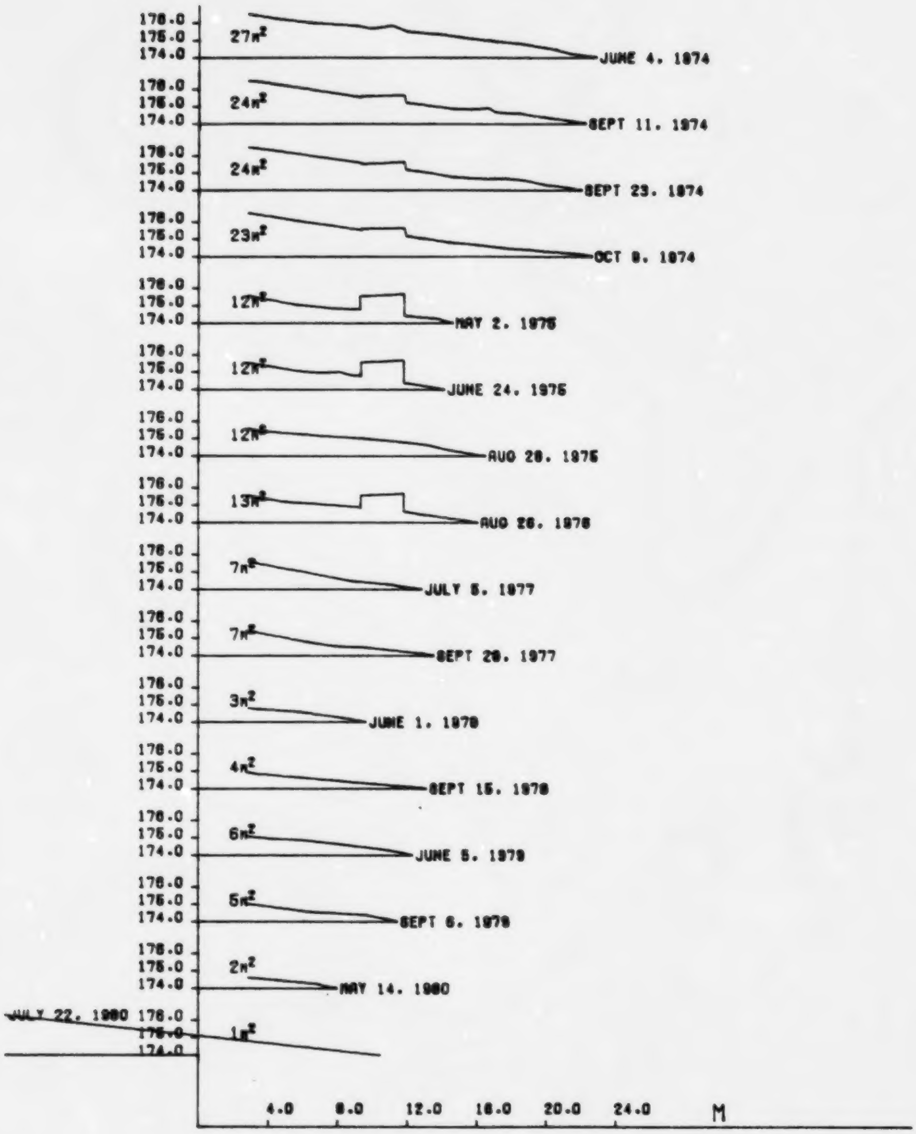
174.0
17m^2
JUNE 3, 1974
16m^2
JUNE 19, 1974
12m^2
JUNE 27, 1974
14m^2
SEPT 10, 1974
12m^2
SEPT 23, 1974
13m^2
OCT 9, 1974
21m^2
MAY 1, 1975
23m^2
JUNE 27, 1975
22m^2
AUG 28, 1975
17m^2
NOV 25, 1975
9m^2
AUG 26, 1976
18m^2
JULY 6, 1977
20m^2
SEPT 29, 1977
36m^2
MAY 30, 1978
30m^2
SEPT 19, 1978
40m^2
JUNE 5, 1979
40m^2
SEPT 6, 1979
38m^2
MAY 14, 1980
38m^2
JULY 23, 1980
39m^2
SEPT 26, 1980
40m^2
JULY 30, 1981
4.0
8.0
12.0
16.0
20.0
M

E-01-027.3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175.0
174.0
27m²
JUNE 4. 1974
24m²
SEPT 11. 1974
24m²
SEPT 23. 1974
23m²
OCT 8. 1974
12m²
MAY 2. 1975
12m²
JUNE 24. 1975
12m²
AUG 28. 1975
13m²
AUG 26. 1976
7m²
JULY 5. 1977
7m²
SEPT 28. 1977
3m²
JUNE 1. 1978
4m²
SEPT 15. 1978
6m²
JUNE 5. 1979
5m²
SEPT 6. 1979
2m²
MAY 14. 1980
JULY 22. 1980
1m²
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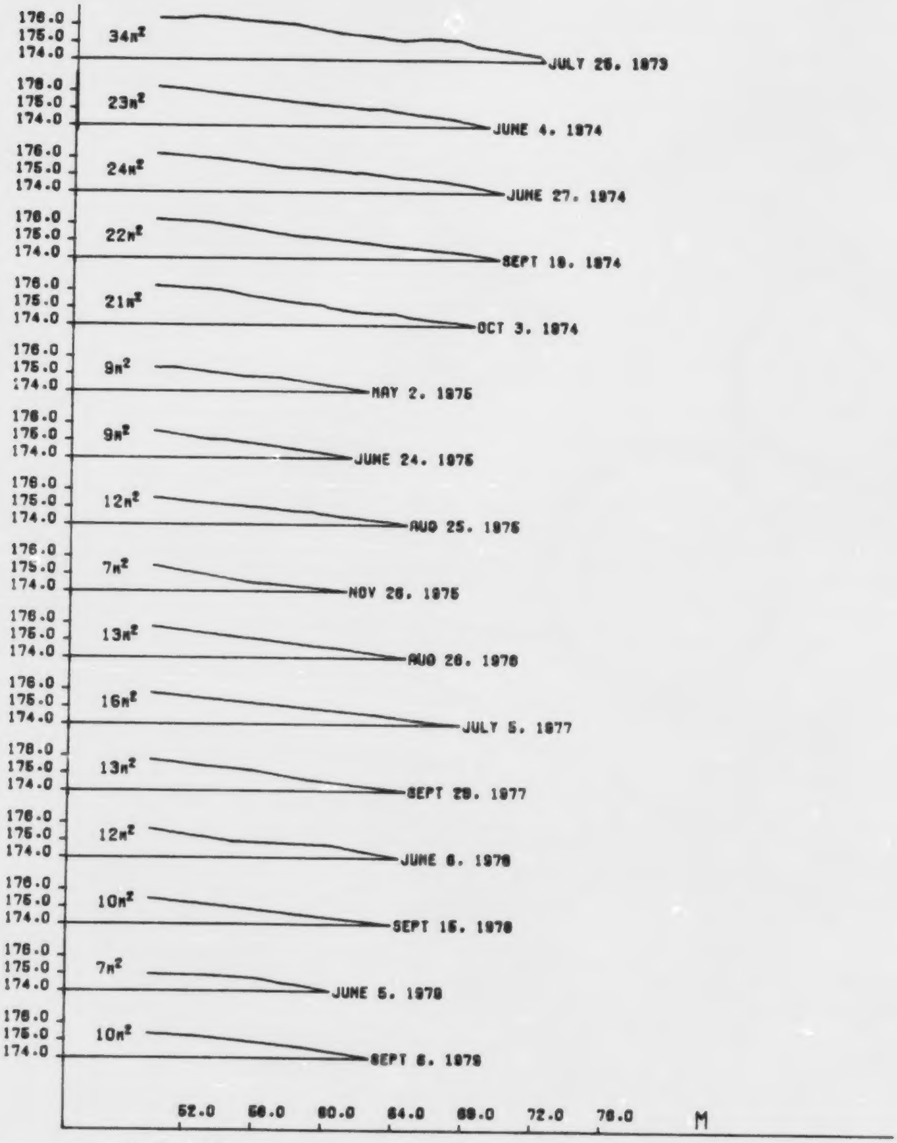
8.0
12.0
16.0
20.0
24.0
M

E-01-027.4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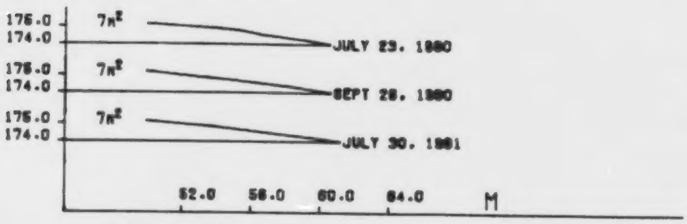
175.0
174.0
34m²
JULY 26, 1973
23m²
JUNE 4, 1974
24m²
JUNE 27, 1974
22m²
SEPT 19, 1974
21m²
OCT 3, 1974
9m²
MAY 2, 1975
9m²
JUNE 24, 1975
12m²
AUG 25, 1975
7m²
NOV 26, 1975
13m²
AUG 26, 1976
16m²
JULY 5, 1977
13m²
SEPT 29, 1977
12m²
JUNE 6, 1978
10m²
SEPT 15, 1978
7m²
JUNE 5, 1979
10m²
SEPT 6, 1979
52.0
56.0
60.0
64.0
68.0
72.0
76.0
M

E-01-028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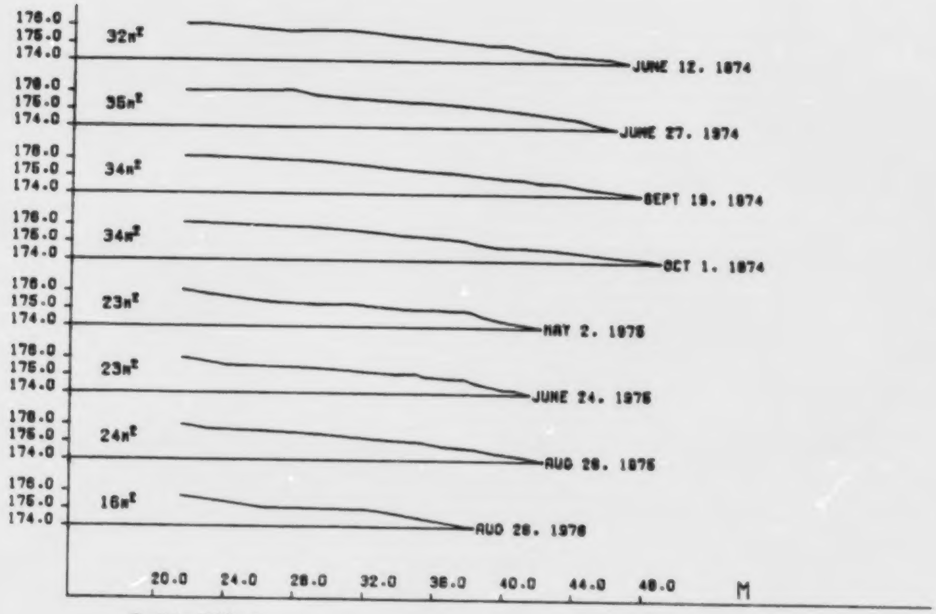
174.0
7M²
JULY 23, 1980
176.0
174.0
7M²
SEPT 26, 1980
176.0
174.0
7M²
JULY 30, 1981
52.0
56.0
60.0
64.0
M

E-01-028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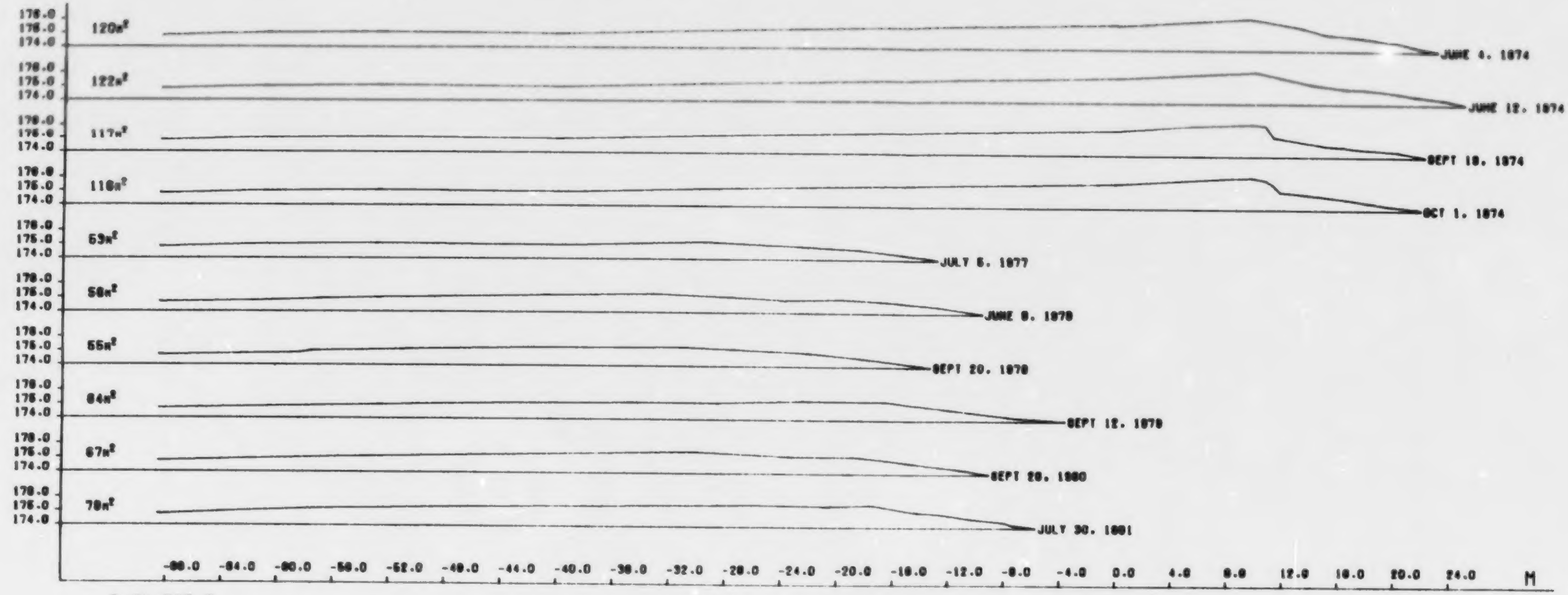
175.0
174.0
32m²
JUNE 12. 1974
176.0
175.0
174.0
35m²
JUNE 27. 1974
176.0
175.0
174.0
34m²
SEPT 19. 1974
176.0
175.0
174.0
34m²
OCT 1. 1974
176.0
175.0
174.0
23m²
MAY 2. 1975
176.0
175.0
174.0
23m²
JUNE 24. 1975
176.0
175.0
174.0
24m²
AUG 28. 1975
176.0
175.0
174.0
16m²
AUG 26. 1976
20.0
24.0
28.0
32.0
36.0
40.0
44.0
48.0
M

E-01-028.4

178.0
176.0
174.0
120m²
122m²
117m²
118m²
53m²
58m²
55m²
64m²
67m²
78m²
JUNE 4, 1974
JUNE 12, 1974
SEPT 18, 1974
OCT 1, 1974
JULY 5, 1977
JUNE 8, 1978
SEPT 20, 1978
SEPT 12, 1979
SEPT 28, 1980
JULY 30, 1981
-68.0
-64.0
-60.0
-56.0
-52.0
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-40.0
-36.0
-32.0
-28.0
-24.0
-20.0
-16.0
-12.0
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0.0
4.0
8.0
12.0
16.0
20.0
24.0
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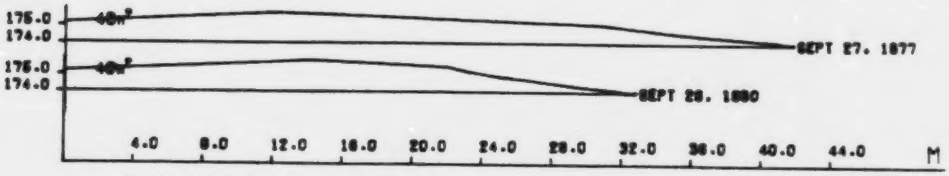
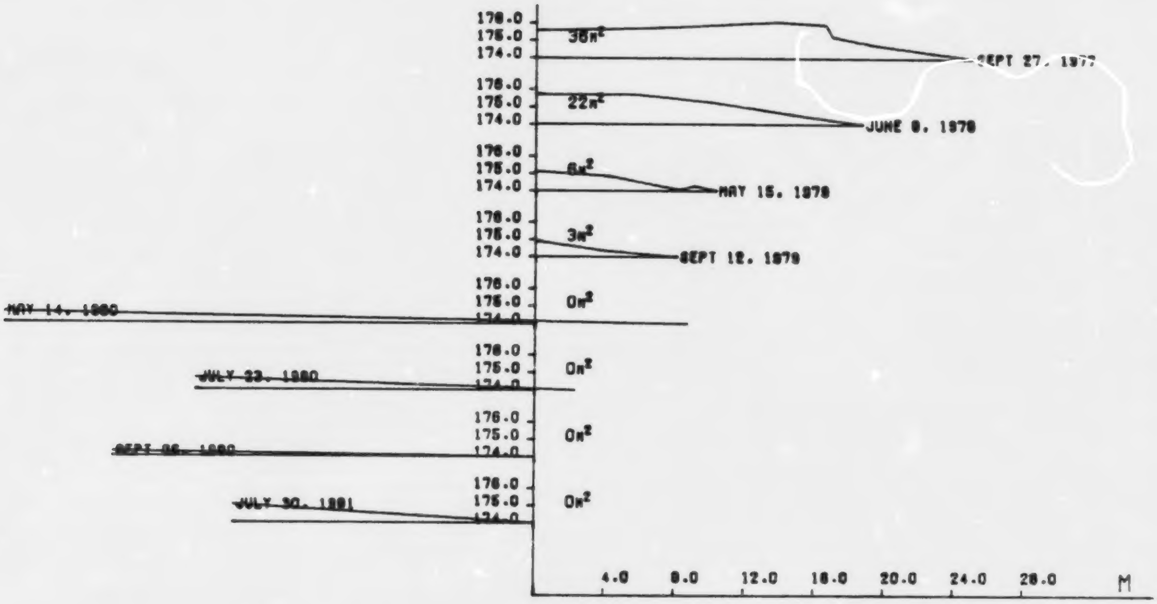
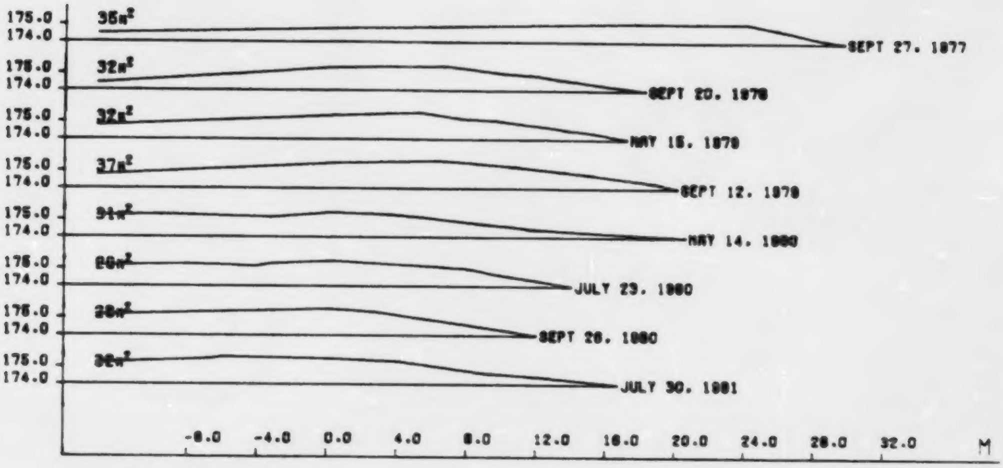
E-01-028.8



E-01-029.1



E-01-029.2

175.0
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35m²
SEPT 27. 1977
32m²
SEPT 20. 1978
32m²
MAY 15. 1979
37m²
SEPT 12. 1979
31m²
MAY 14. 1980
26m²
JULY 23. 1980
28m²
SEPT 26. 1980
30m²
JULY 30. 1981
-8.0
-4.0
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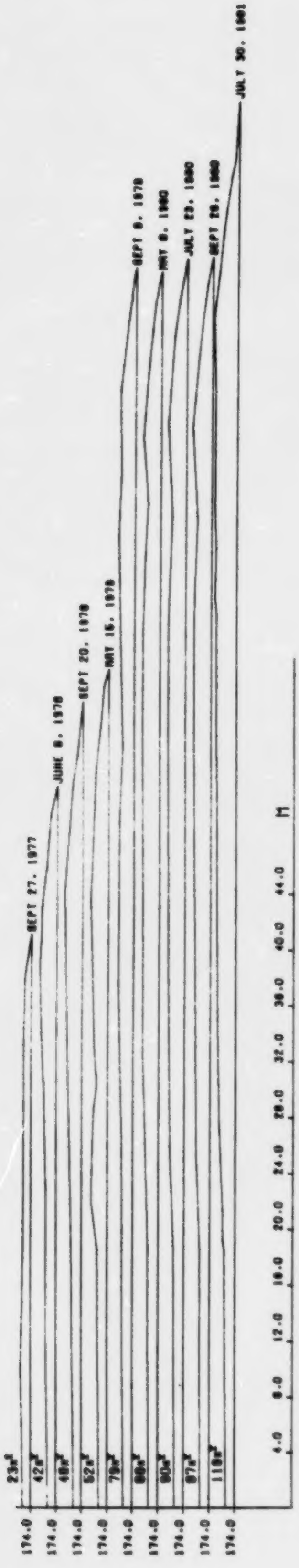
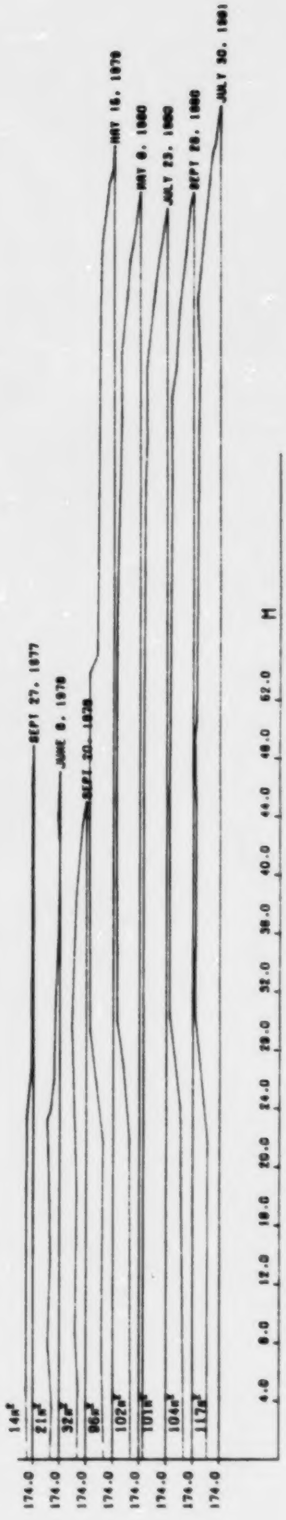
8.0
12.0
16.0
20.0
24.0
28.0
32.0
M

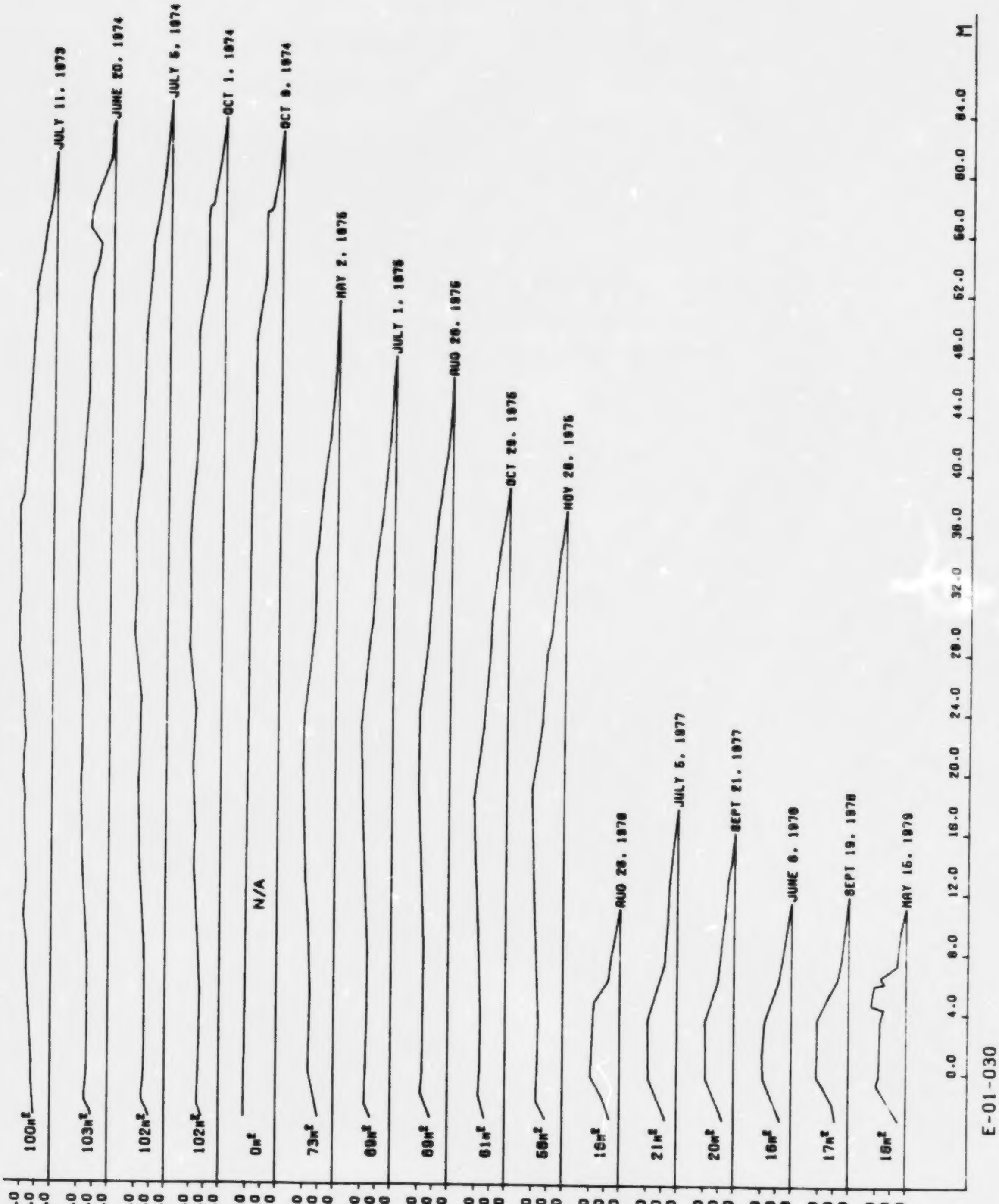
E-01-029.3



E-01-029.4



E-01-029.5

JULY 11, 1973
JUNE 20, 1974
JULY 5, 1974
OCT 1, 1974
OCT 8, 1974
MAY 2, 1976
JULY 1, 1976
AUG 26, 1976
OCT 28, 1976
NOV 28, 1976
AUG 28, 1976
JULY 5, 1977
SEPT 21, 1977
JUNE 6, 1978
SEPT 19, 1978
MAY 15, 1979
N/A
100m²
103m²
102m²
102m²
0m²
73m²
69m²
69m²
61m²
58m²
16m²
21m²
20m²
16m²
17m²
18m²
176.0
175.0
174.0
0.0
4.0
8.0
12.0
16.0
20.0
24.0
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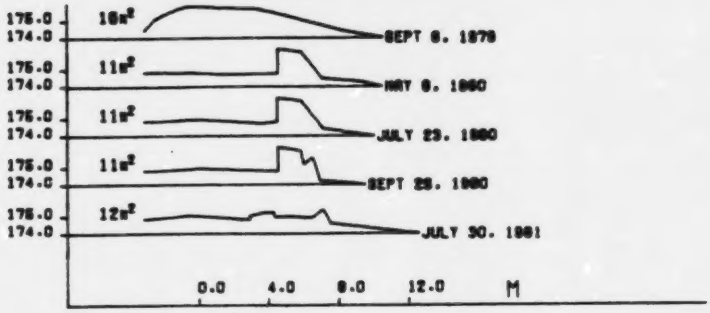
36.0
40.0
44.0
48.0
52.0
56.0
60.0
64.0
M

E-01-030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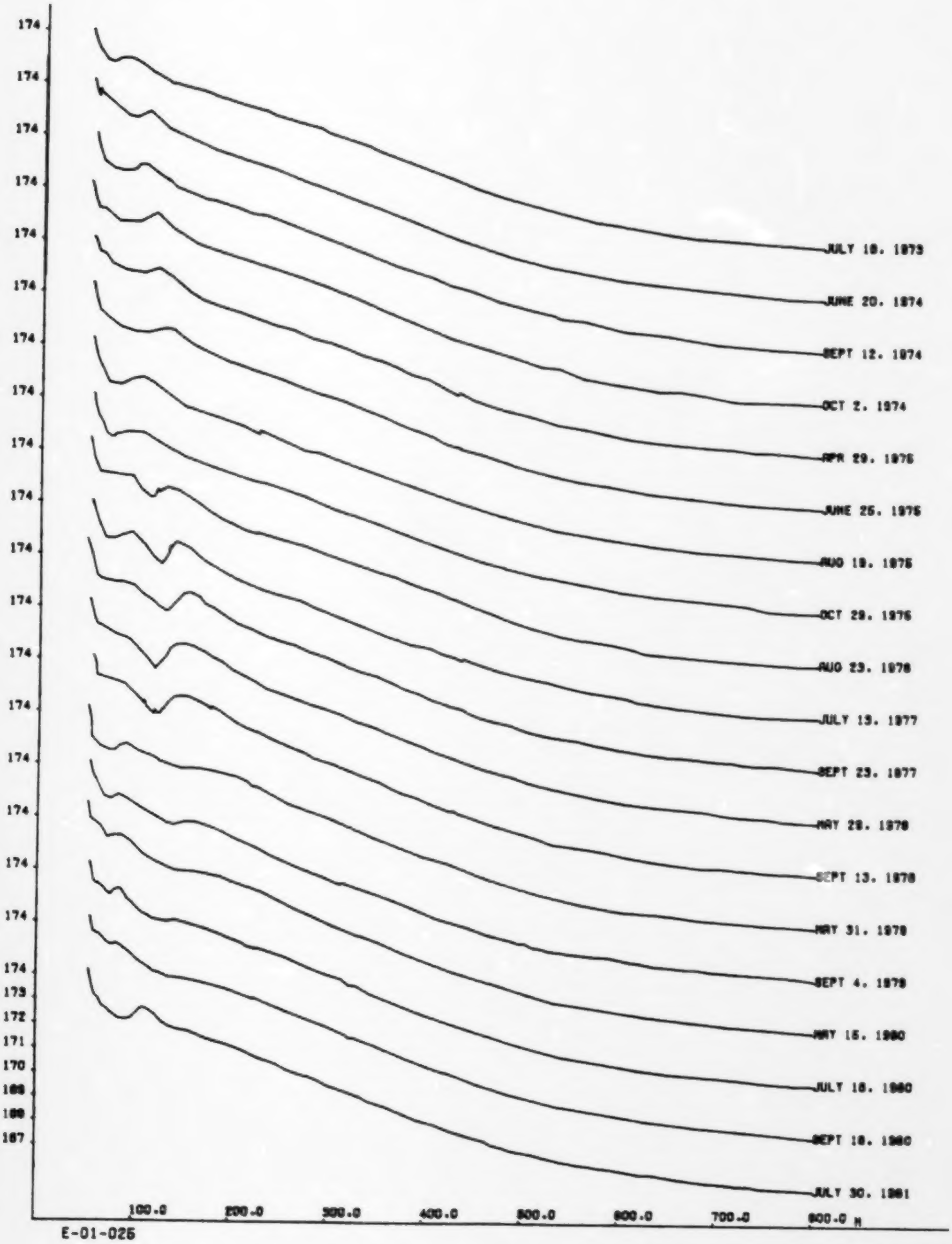
11m^2
MAY 8. 1980
176.0
174.0
11m^2
JULY 23. 1980
176.0
174.0
11m^2
SEPT 25. 1980
176.0
174.0
12m^2
JULY 30. 1981
0.0
4.0
8.0
12.0
M

E-01-030

APPENDIX 2

Nearshore and Offshore Profile Plots 1974-1981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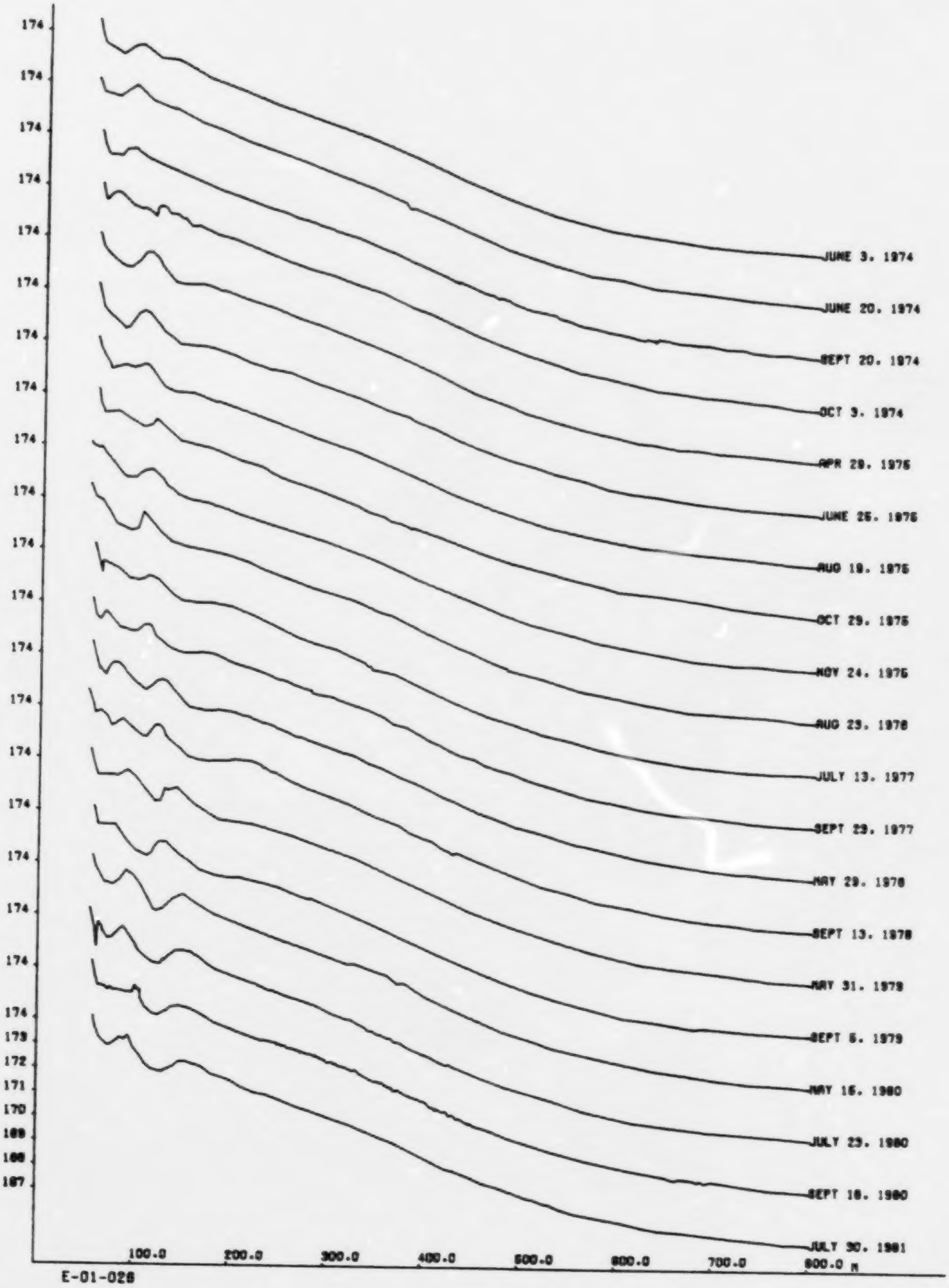
169
168
167
JULY 18. 1973
JUNE 20. 1974
SEPT 12. 1974
OCT 2. 1974
APR 29. 1975
JUNE 25. 1975
AUG 19. 1975
OCT 29. 1975
AUG 23. 1976
JULY 13. 1977
SEPT 23. 1977
MAY 29. 1978
SEPT 13. 1978
MAY 31. 1979
SEPT 4. 1979
MAY 15. 1980
JULY 16. 1980
SEPT 18. 1980
JULY 30. 1981
100.0
200.0
300.0
400.0
500.0
600.0
700.0
800.0 M

E-01-025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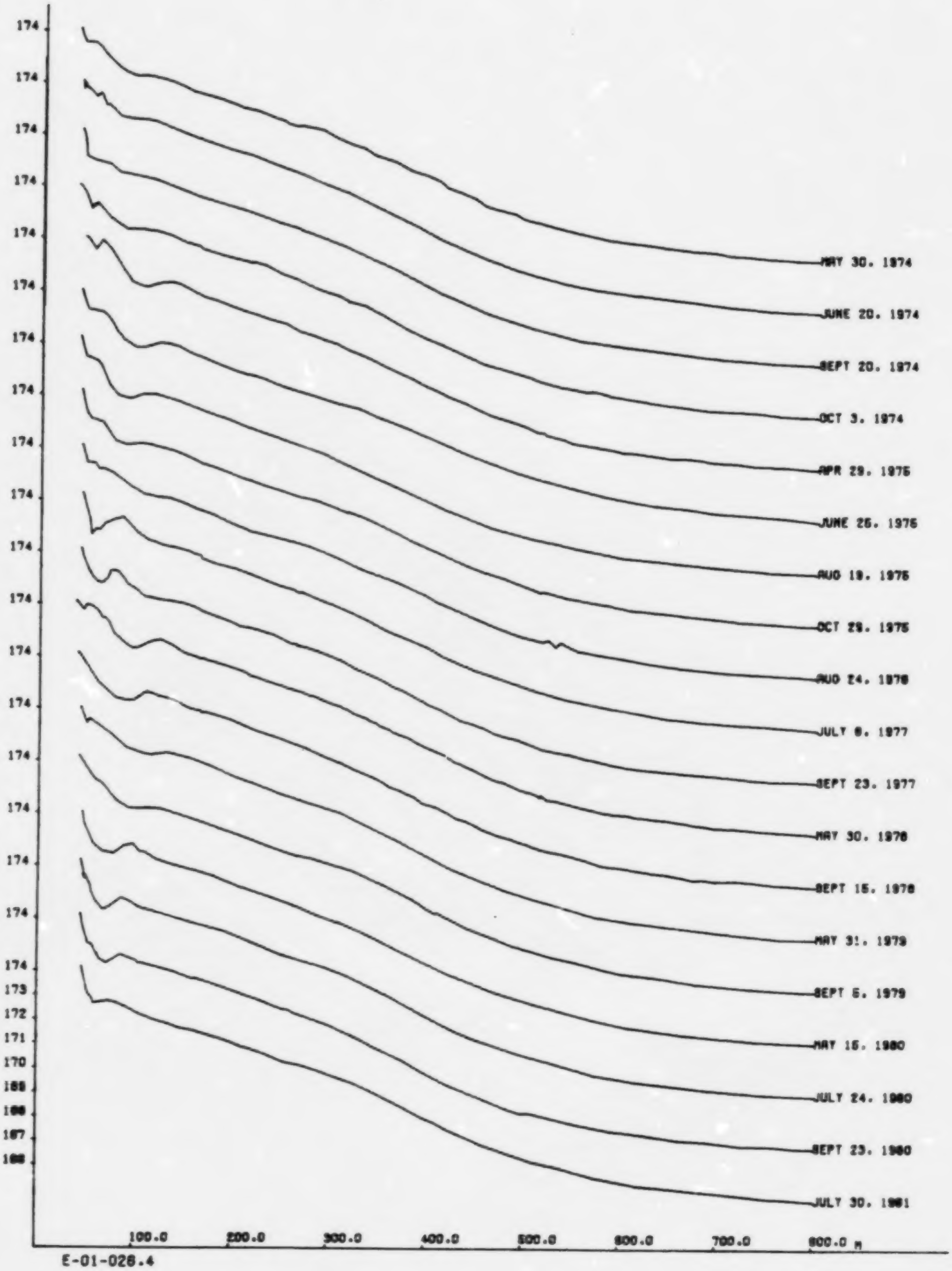
173
172
171
170
169
168
167
100.0
200.0
300.0
400.0
500.0
600.0
700.0
800.0 M
JUNE 3. 1974
JUNE 20. 1974
SEPT 20. 1974
OCT 3. 1974
APR 28. 1975
JUNE 25. 1975
AUG 19. 1975
OCT 29. 1975
NOV 24. 1975
AUG 23. 1976
JULY 13. 1977
SEPT 29. 1977
MAY 29. 1978
SEPT 13. 1978
MAY 31. 1979
SEPT 6. 1979
MAY 15. 1980
JULY 23. 1980
SEPT 18. 1980
JULY 30. 1981

E-01-028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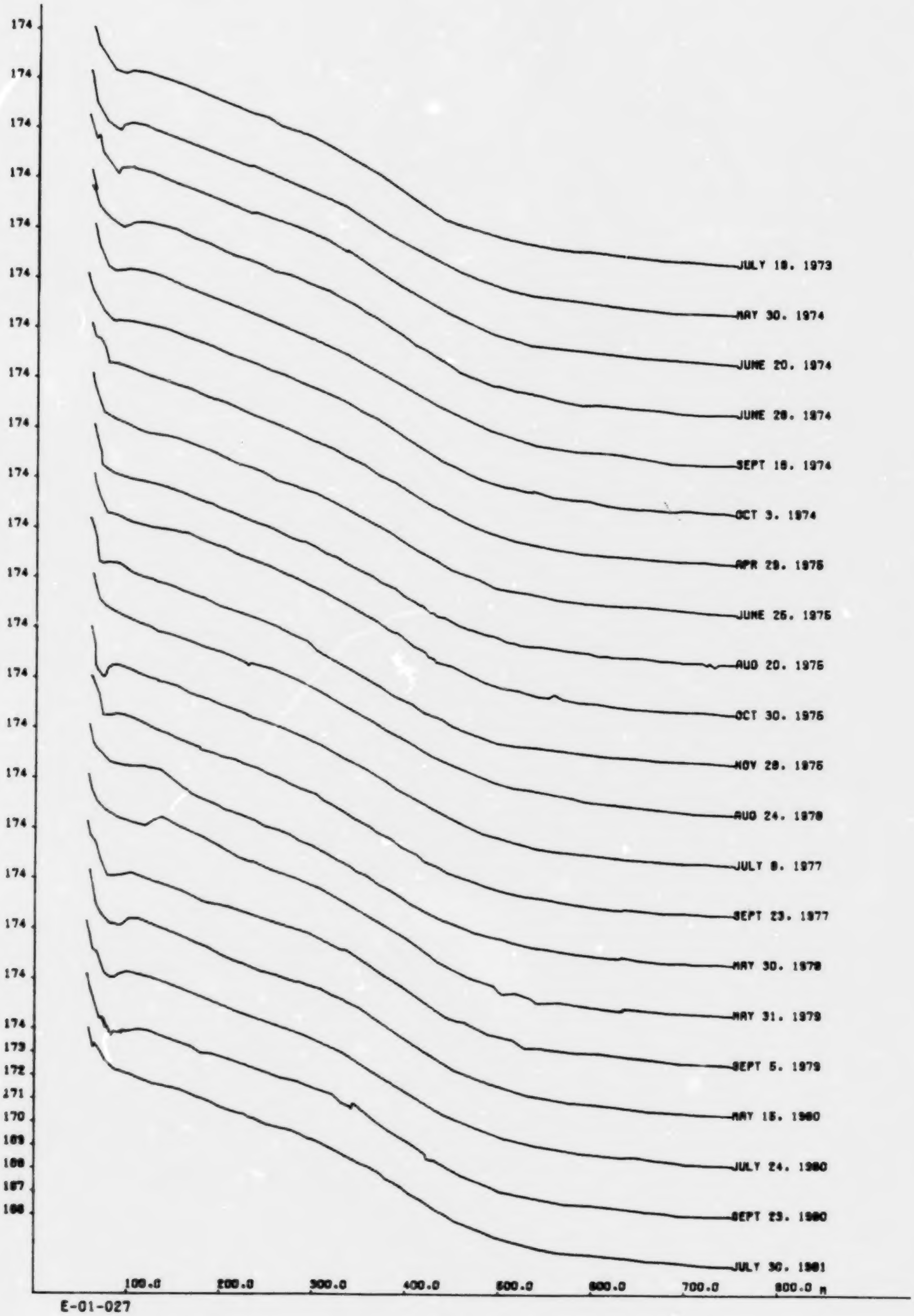
171
170
169
168
167
166
MAY 30. 1974
JUNE 20. 1974
SEPT 20. 1974
OCT 3. 1974
APR 29. 1975
JUNE 26. 1975
AUG 19. 1975
OCT 28. 1975
AUG 24. 1976
JULY 8. 1977
SEPT 23. 1977
MAY 30. 1978
SEPT 15. 1978
MAY 31. 1979
SEPT 5. 1979
MAY 15. 1980
JULY 24. 1980
SEPT 23. 1980
JULY 30. 1981
100.0
200.0
300.0
400.0
500.0
600.0
700.0
800.0 M

E-01-026.4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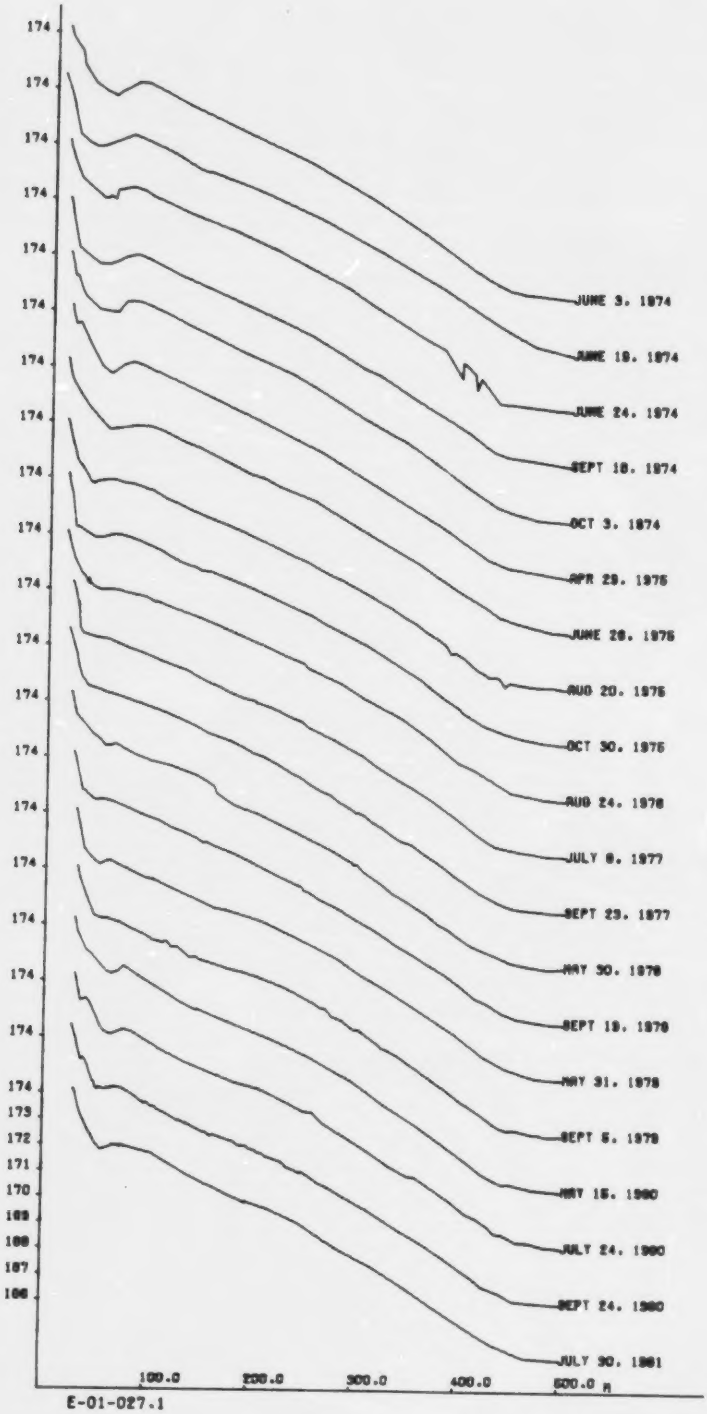
171
170
169
168
167
166
JULY 18. 1973
MAY 30. 1974
JUNE 20. 1974
JUNE 28. 1974
SEPT 18. 1974
OCT 3. 1974
APR 29. 1975
JUNE 25. 1975
AUG 20. 1975
OCT 30. 1975
NOV 28. 1975
AUG 24. 1976
JULY 8. 1977
SEPT 23. 1977
MAY 30. 1978
MAY 31. 1979
SEPT 5. 1979
MAY 15. 1980
JULY 24. 1980
SEPT 23. 1980
JULY 30. 1981
100.0
200.0
300.0
400.0
500.0
600.0
700.0
800.0 m

E-01-027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172
171
170
169
168
167
166
JUNE 3. 1974
JUNE 19. 1974
JUNE 24. 1974
SEPT 18. 1974
OCT 3. 1974
APR 29. 1975
JUNE 26. 1975
AUG 20. 1975
OCT 30. 1975
AUG 24. 1976
JULY 8. 1977
SEPT 23. 1977
MAY 30. 1978
SEPT 19. 1978
MAY 31. 1979
SEPT 5. 1979
MAY 15. 1980
JULY 24. 1980
SEPT 24. 1980
JULY 30. 1981
100.0
200.0
300.0
400.0
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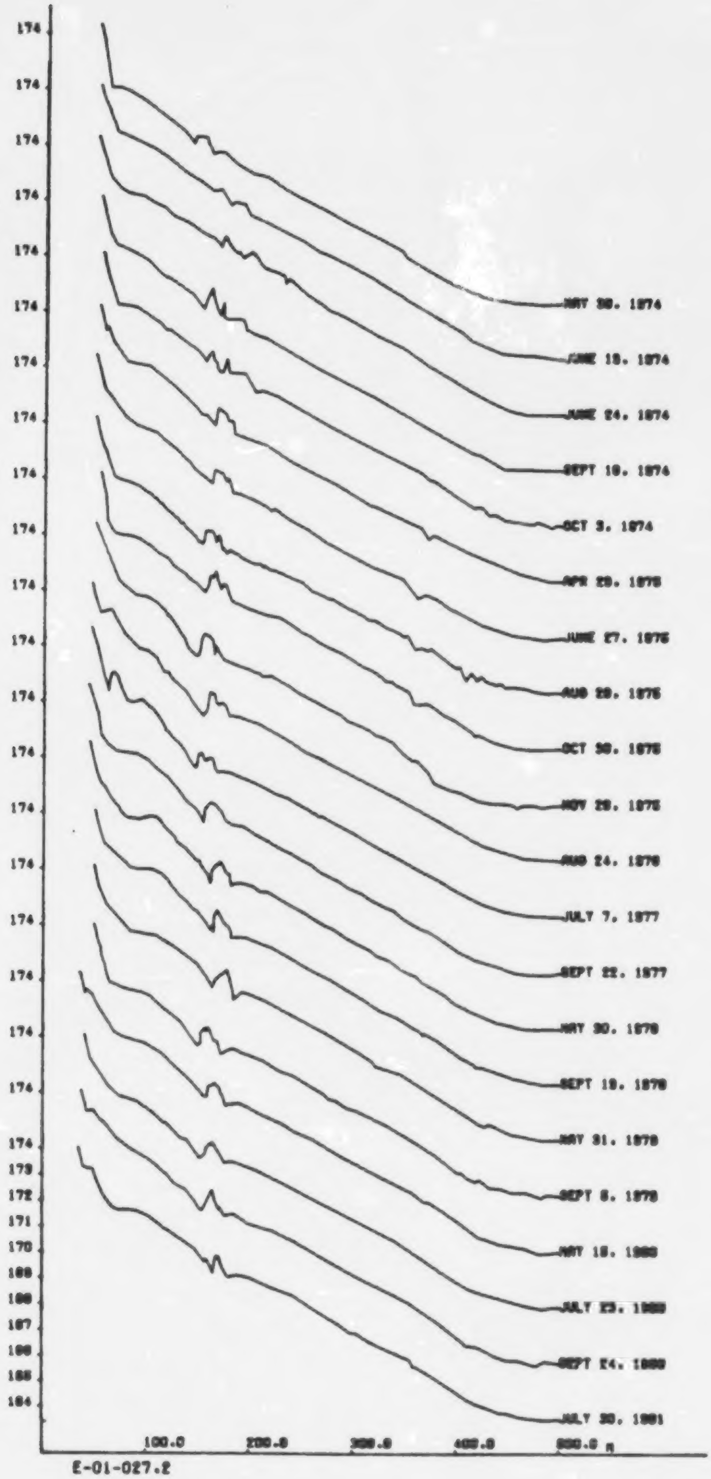
E-01-027.1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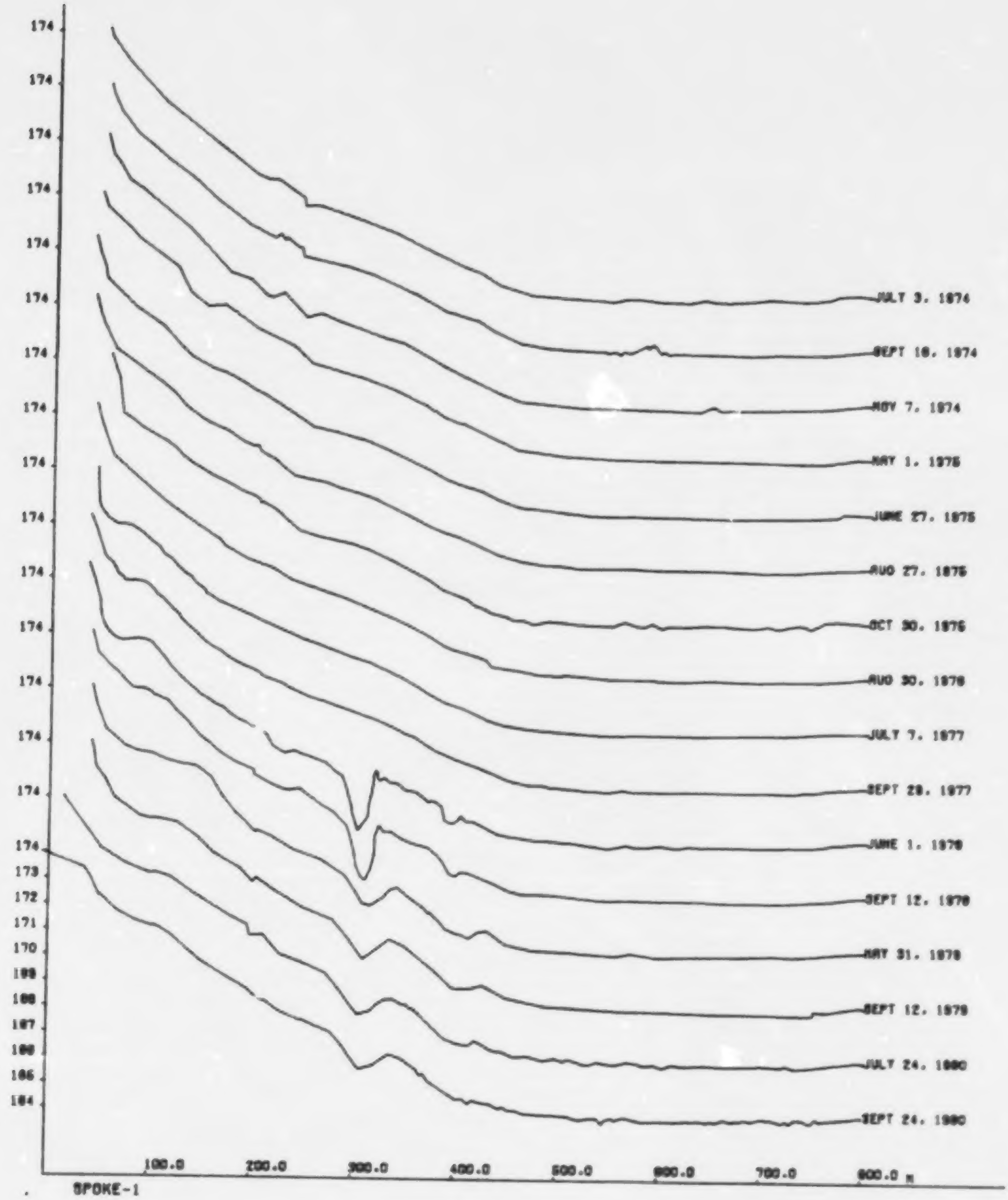
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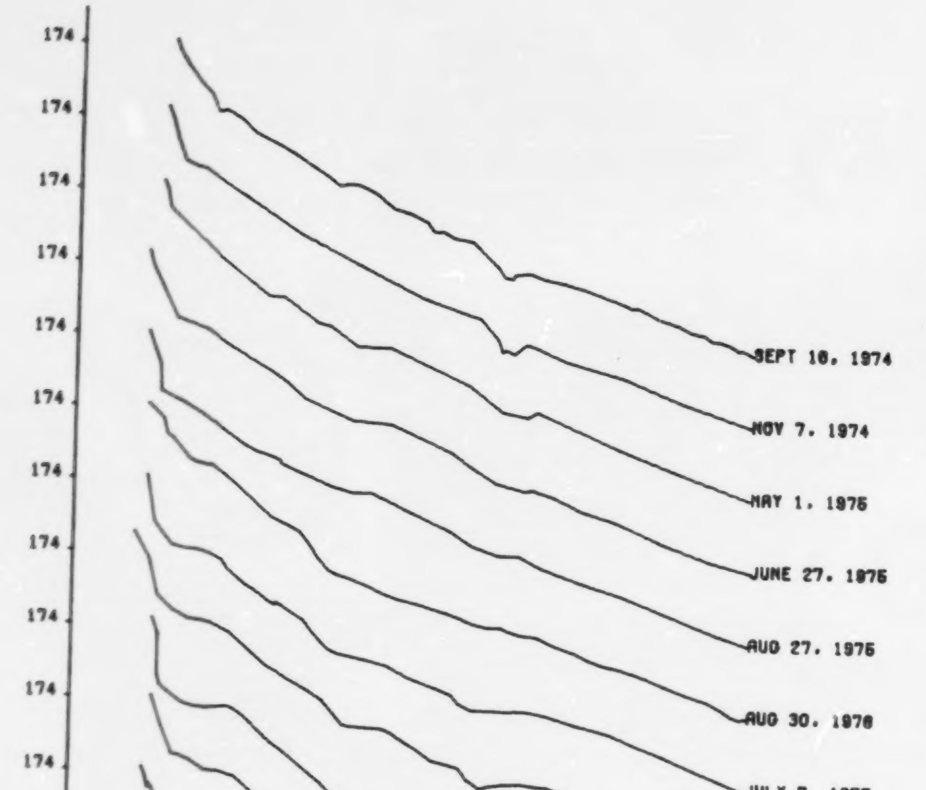
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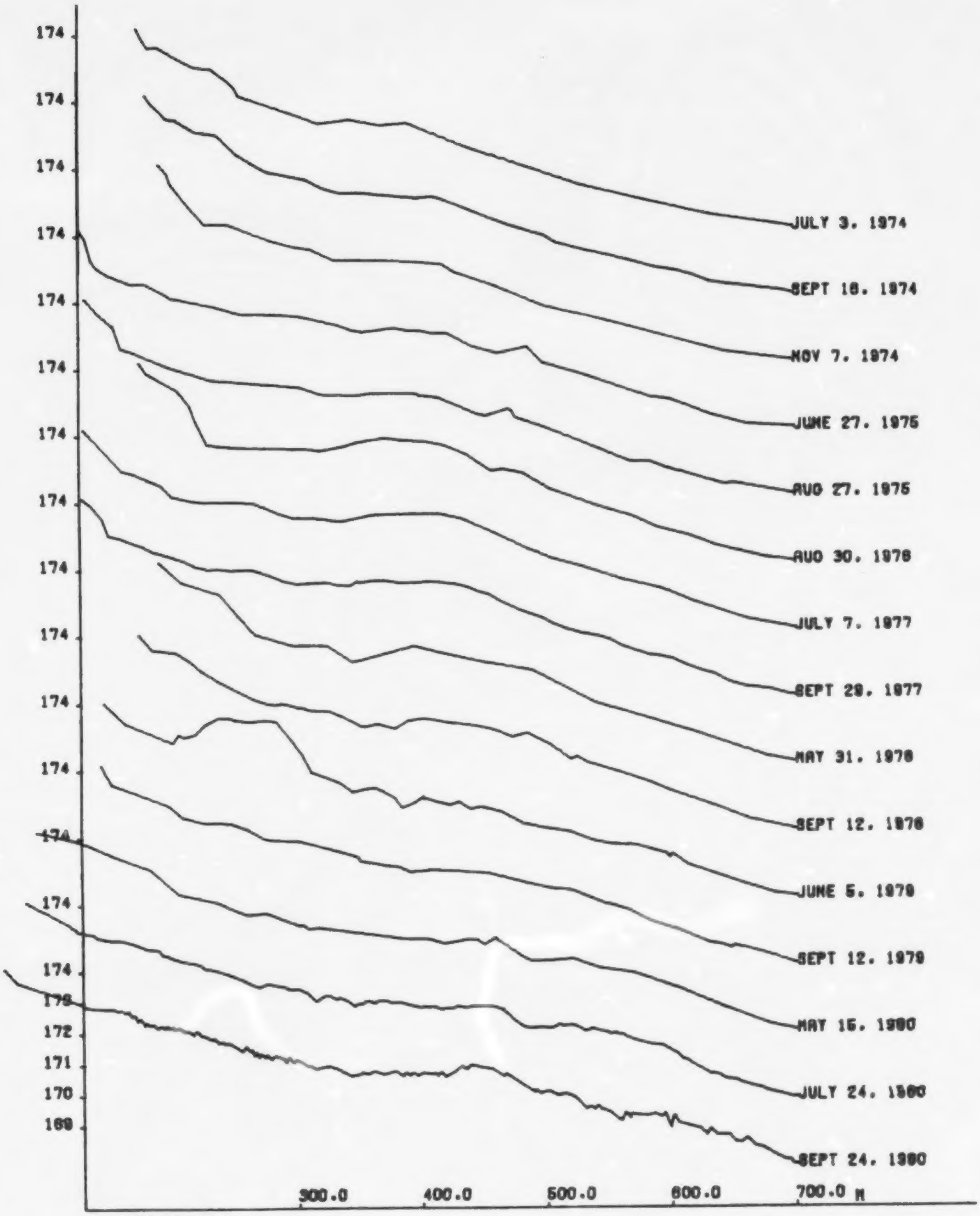
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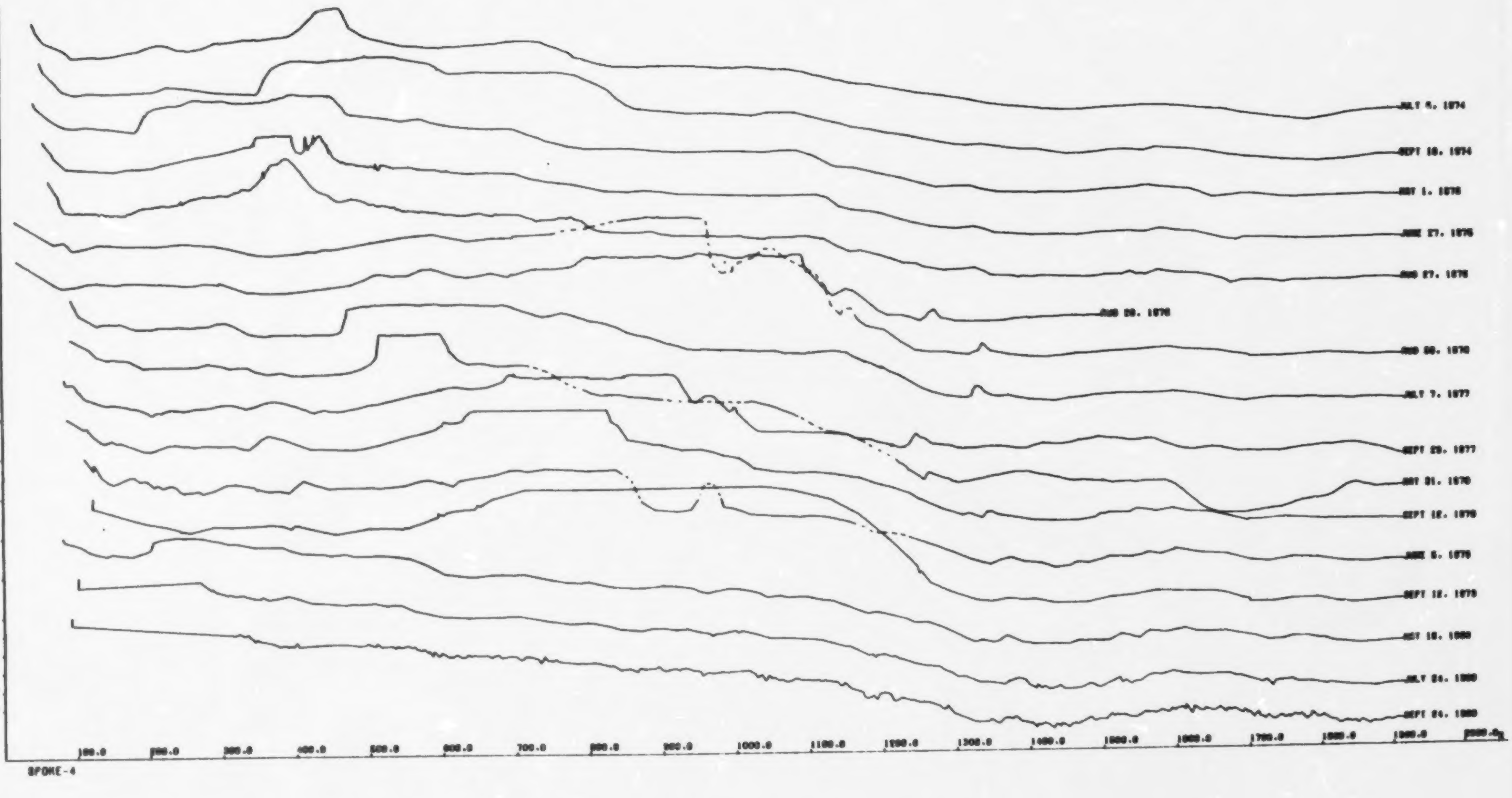

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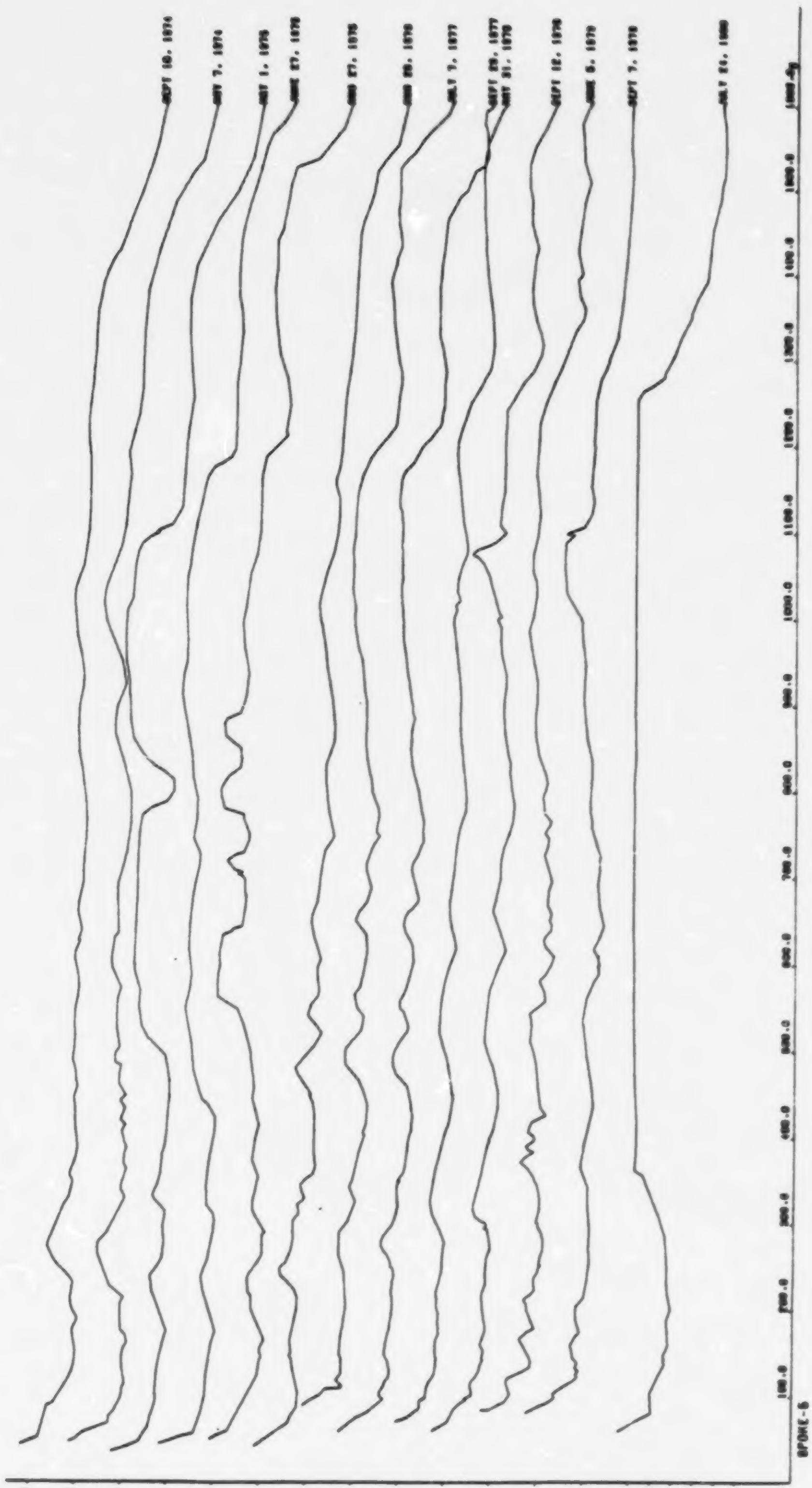
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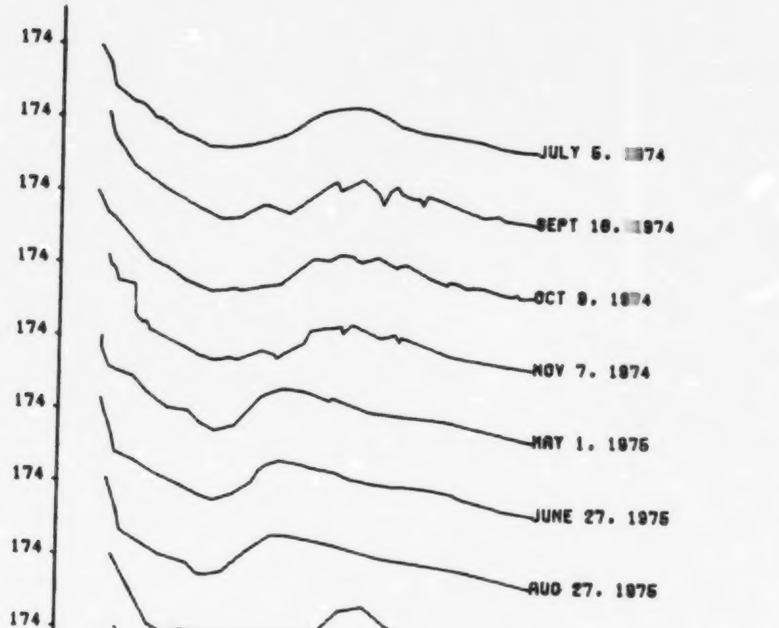
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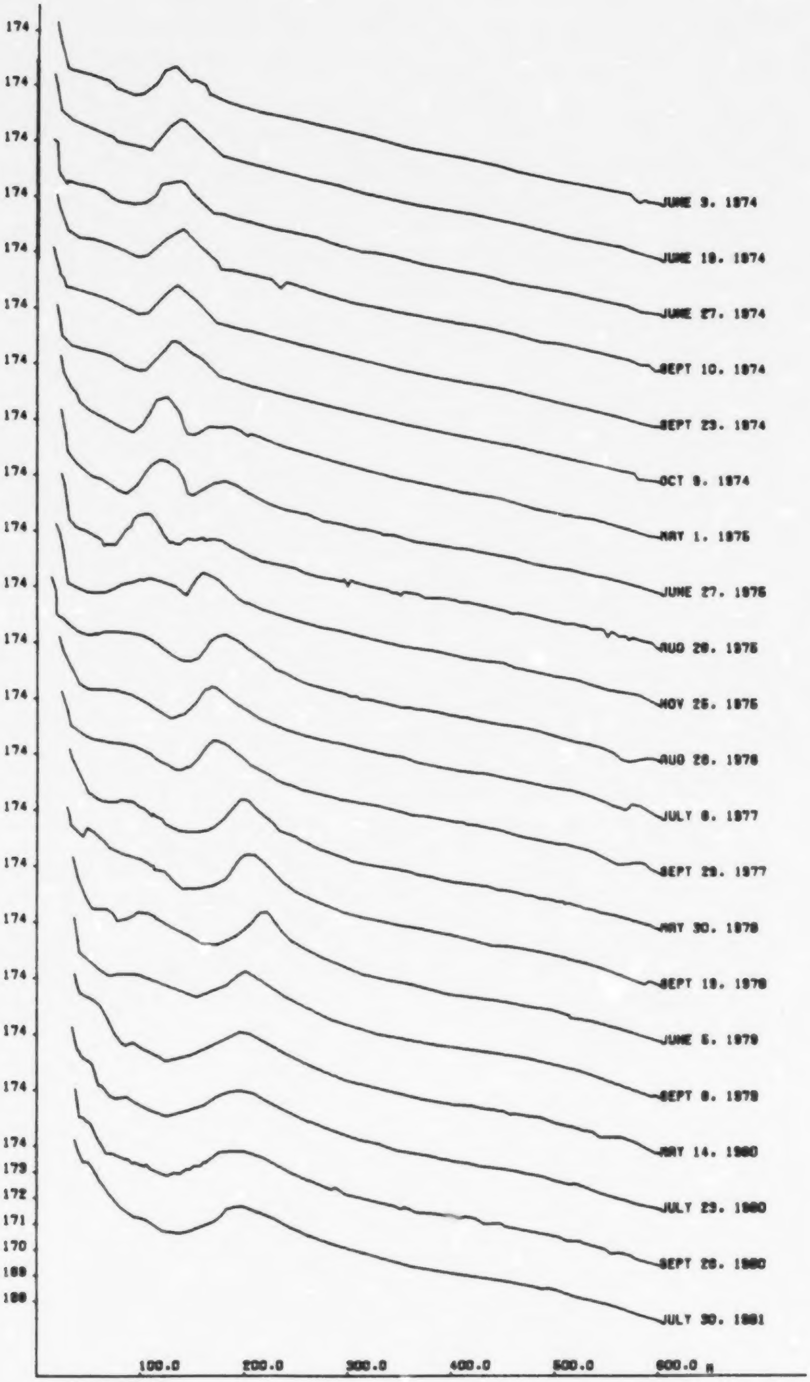
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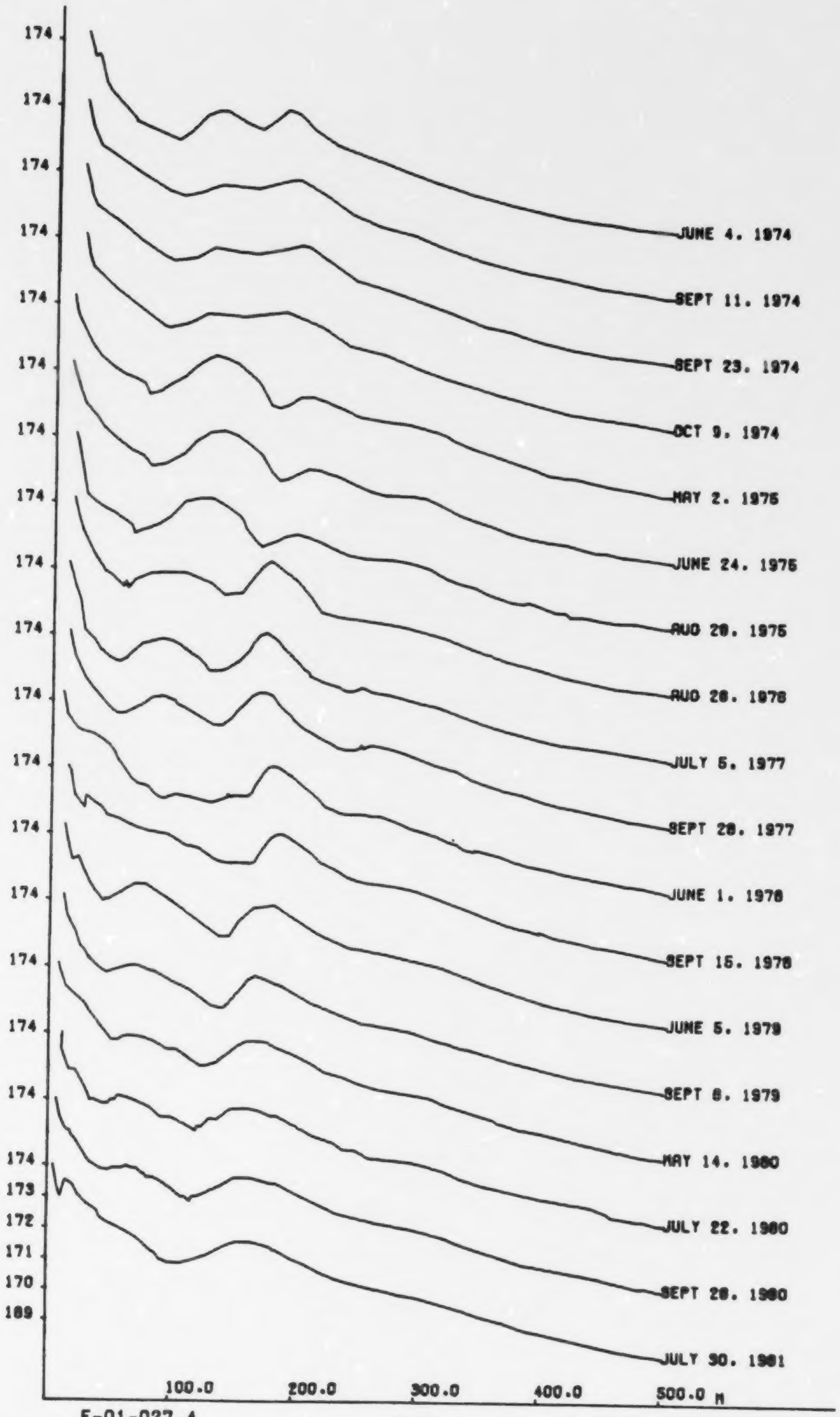
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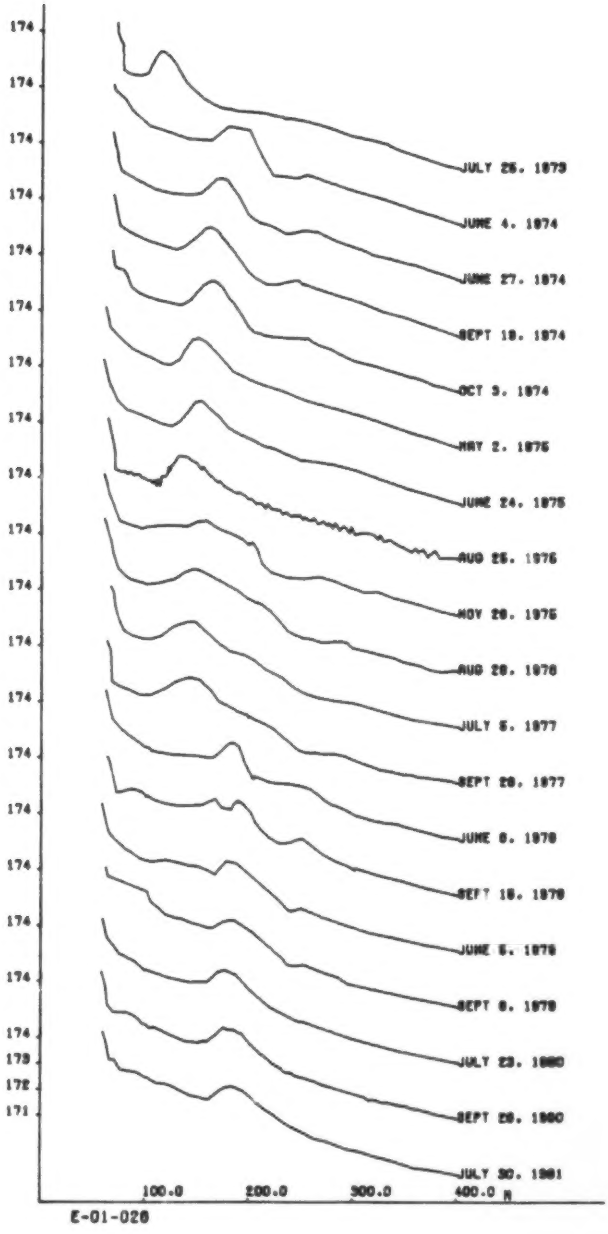
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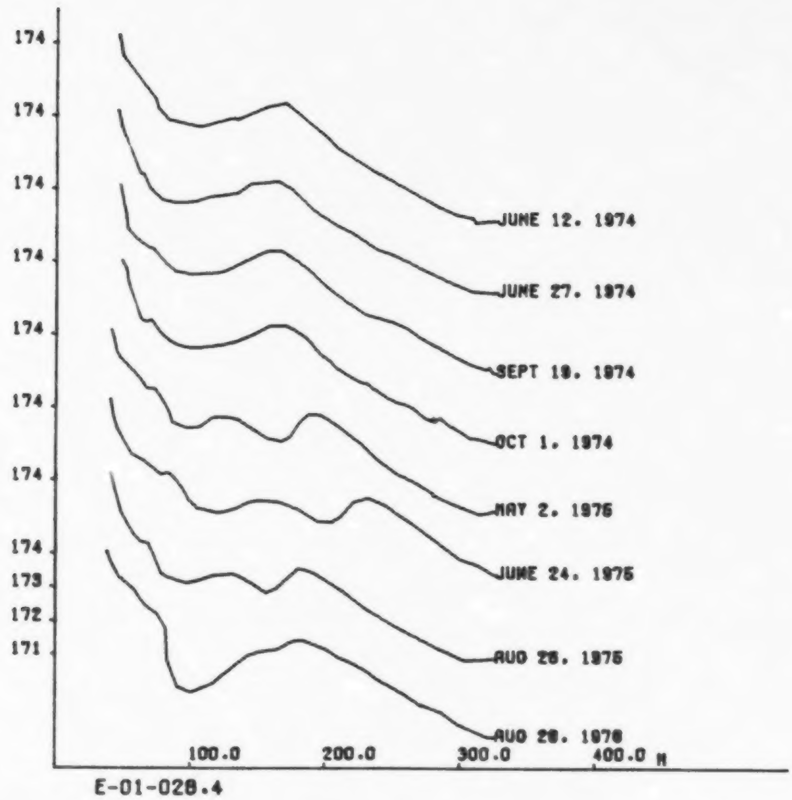
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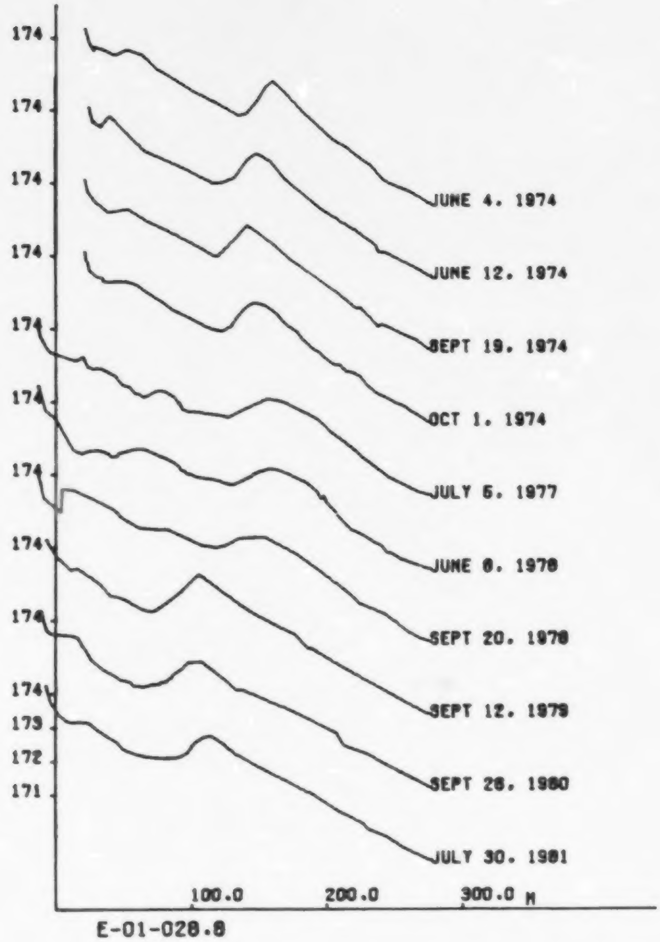
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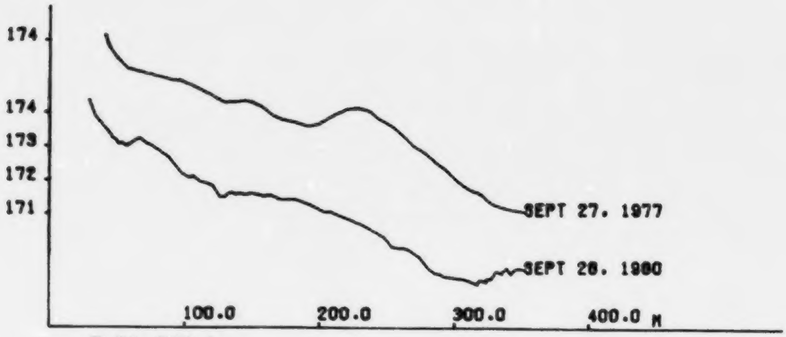

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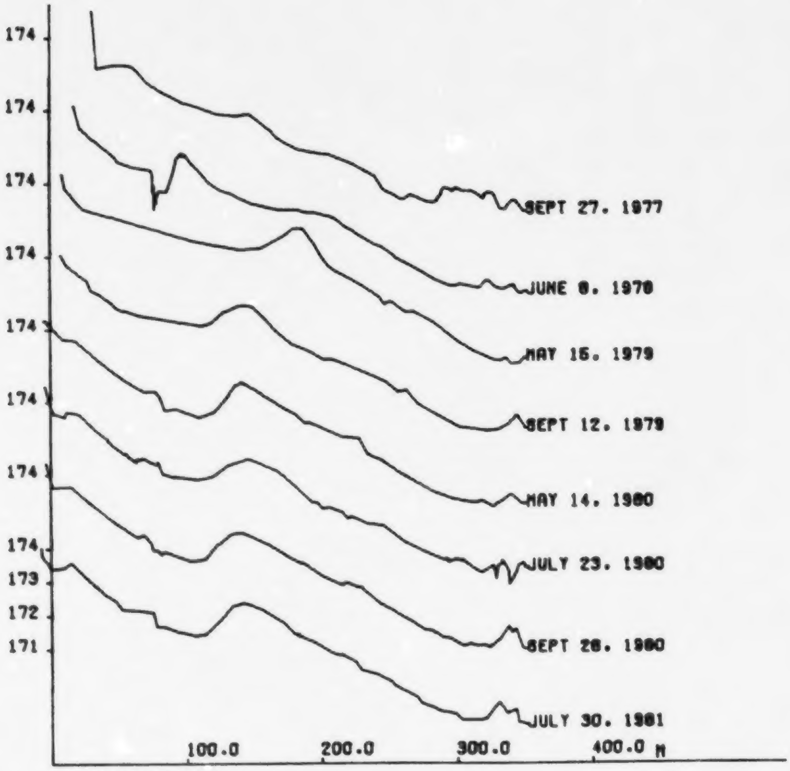

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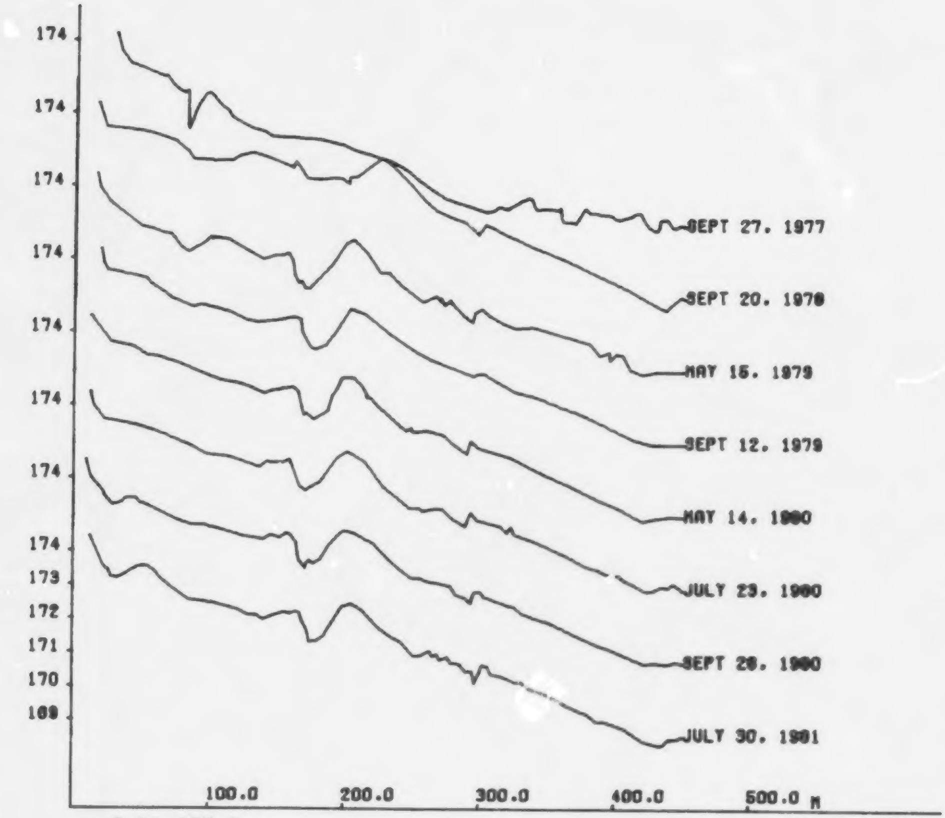
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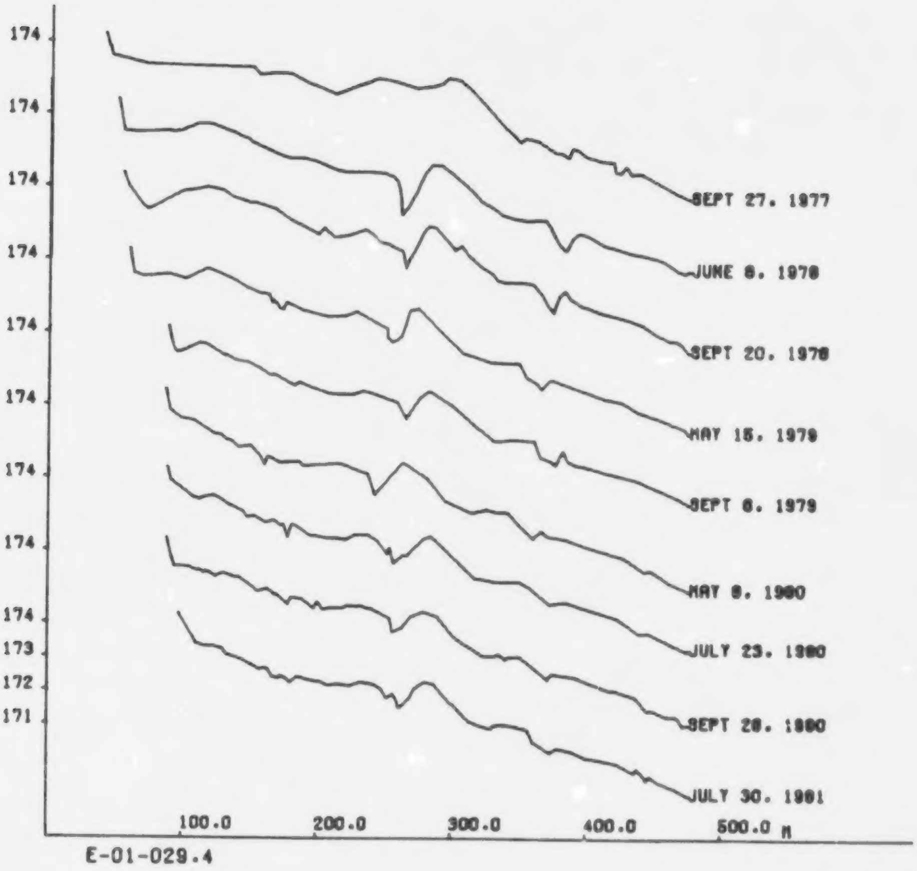
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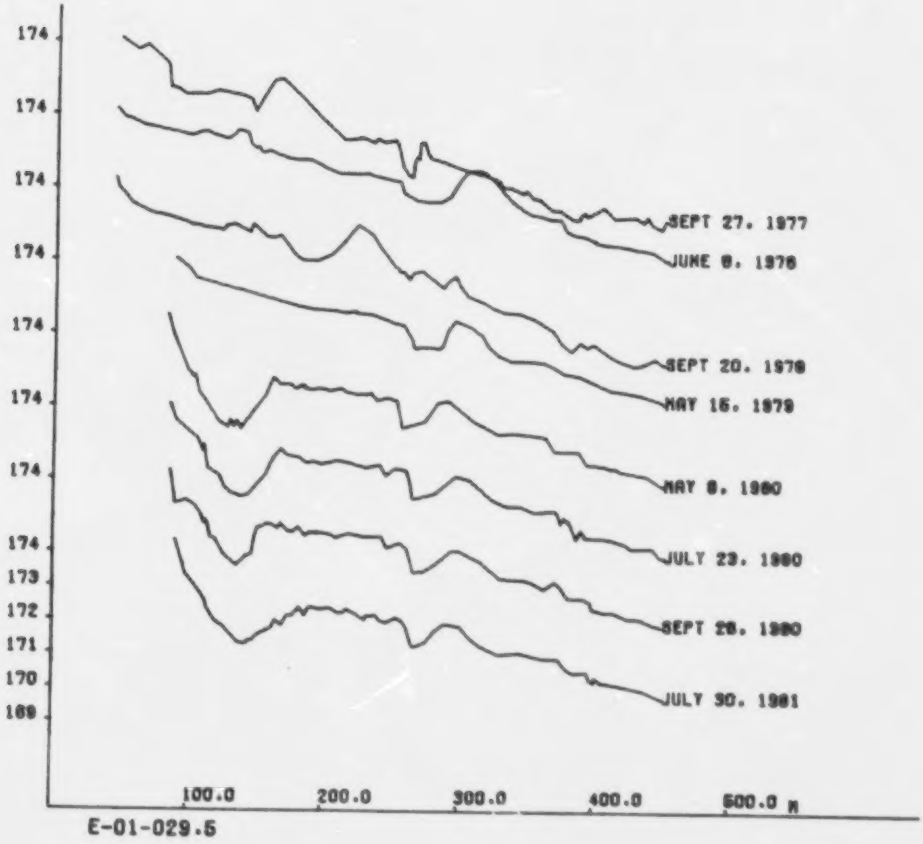
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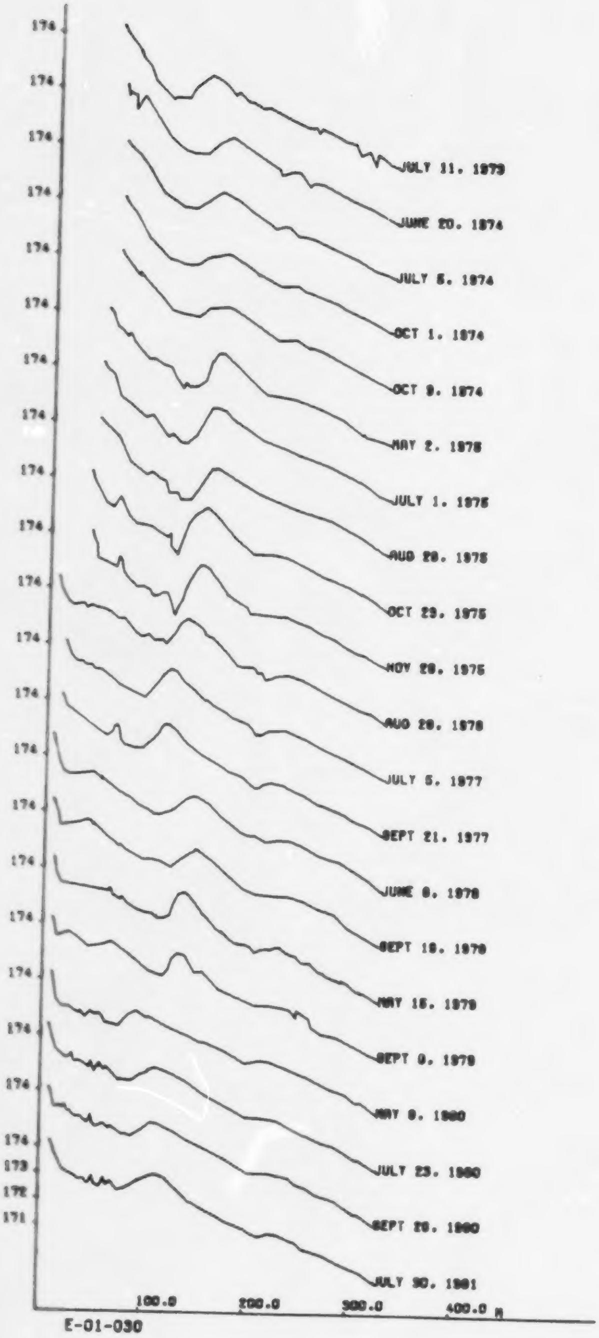
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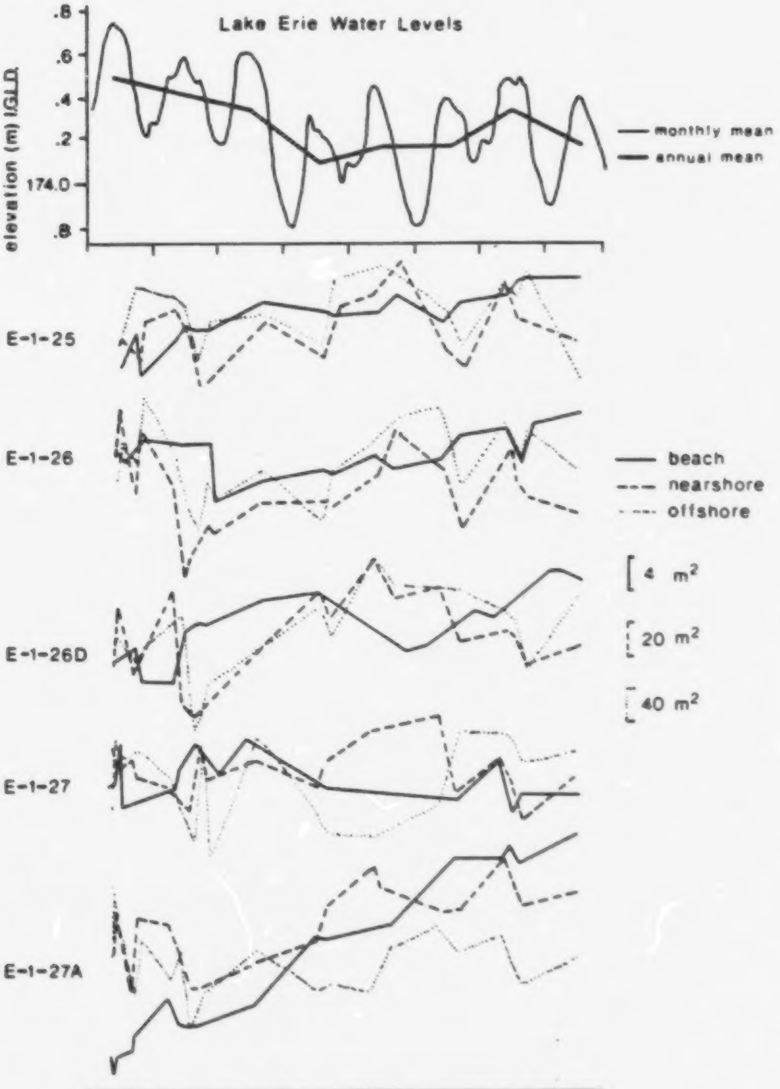
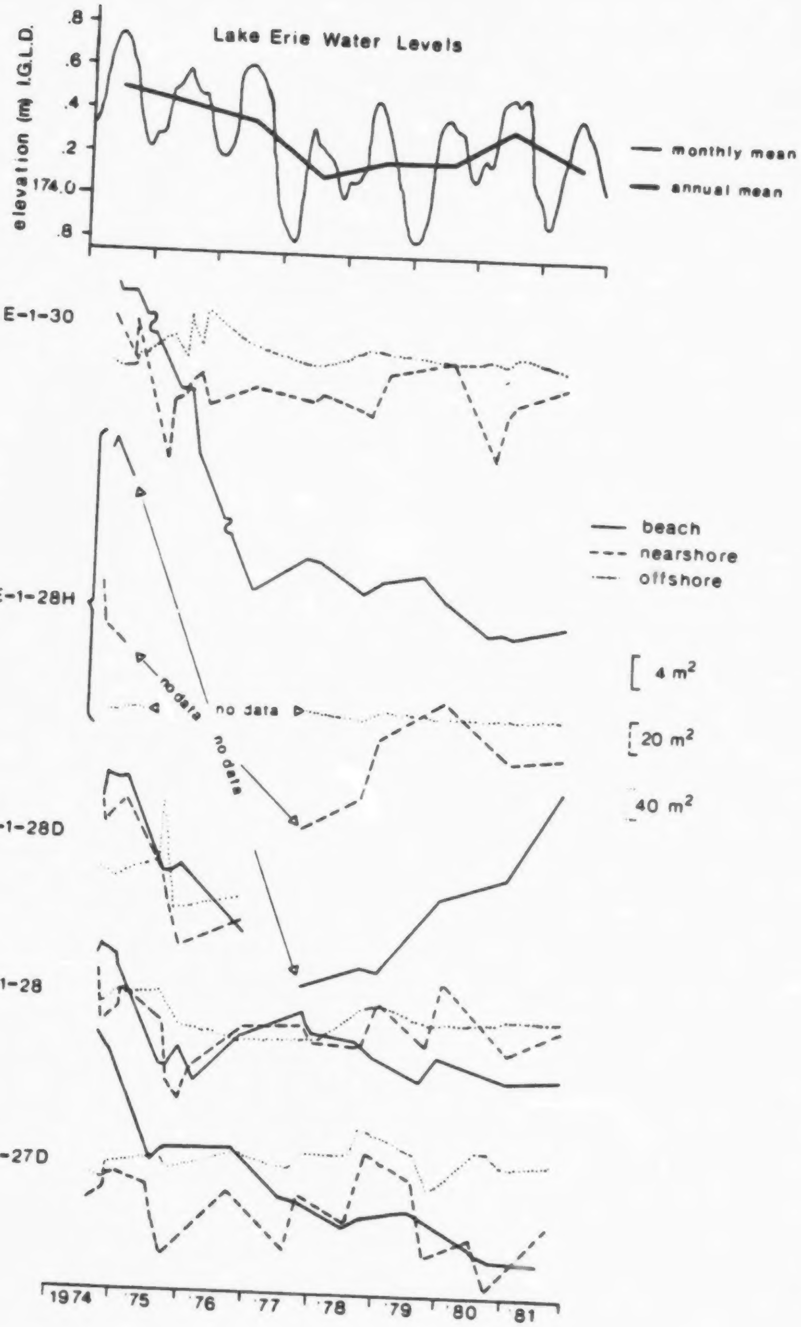
APPENDIX 3

Time-Series Observations of Beach, Nearshore and Offshore Sediment Volumes 1974-1981



Time-Series Observations of Beach, Nearshore and Offshore Sediment Volumes (m^2) of the WEST SIDE of Point Pelee 1974-1981



Time-Series Observations of Beach, Nearshore and Offshore Volumes (m^2) of the EAST SIDE of Point Pelee 1974-1981